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UNITED STATES
DEPARTMENT OF THE INTERIOR
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SAFETY IN THE MINING INDUSTRY

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D. HARRINGTON, J. H. EAST, JR., AND R. G. WARNCKE

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SAFETY IN THE MINING INDUSTRY[1]

By D. Harrington,[2] J. H. East, Jr.,[3]
and R. G. Warncke[3]

CONTENTS

	Page
Introduction	7
Acknowledgment	12
Coal mining	12
Principal causes of accidents, all coal mines	19
Accidents due to explosives	22
Bituminous coal and lignite	23
Accidents in coal mines	27
Causes of fatal accidents in underground bituminous-coal and lignite mines	32
Falls of roof and coal	32
Haulage	35
Gas or dust explosions	36
Explosives	36
Fatal accidents caused by electricity	37
Shaft accidents	39
Major coal-mine disasters	40
Underground mines and surface plants	57
Strip coal mining	59
Mechanical loading of coal	64
Rock dusting in bituminous-coal beds upon fatal-accident rates	66
Effect of thickness of coal beds upon fatal-accident rates	70
The problem of small mines	72
Age of miners	75
Some examples of good safety records at bituminous-coal and lignite mines	79
Anthracite	80
Fatal accidents underground, by principal causes	88
Falls of roof and coal	88
Haulage	90
Explosives	90

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7485."

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CONTENTS (Cont'd.)

Page

Anthracite (Cont'd.)
- Underground workings 91
- Anthracite strippings 92
- Some excellent safety records at anthracite mines 93

Metal and nonmetallic-mineral mines 94
- Principal causes of underground accidents 99
  - Falling rock or ore from roof (back) or walls 100
  - Explosives 101
  - Haulage 101
  - Falling down chutes or raises or into winzes 101
- Shaft mines 102
- Copper mines 102
- Iron mines 105
- Lead-zinc mines in the Mississippi Valley 108
- Gold, silver, and miscellaneous metal mines 110
- Nonmetallic-mineral mines 112
- Relative hazards of various mining methods 114
- Outstanding safety records at metal and nonmetallic-mineral mines 116
  - Iron-ore mines 116
  - Molybdenum mine 116
  - Copper mines 117
  - Lead-zinc mine 117
  - Gold mine 117
  - Open-cut mines 117
  - Open-cut mines operated without lost-time accidents 117

Quarrying 118
- Cement rock 128
- Limestone 130
- Limestone (chief product lime) 131
- Granite 131
- Marble 132
- Sandstone 132
- Slate 133
- Trap rock 133
- Accident-frequency rates by kind of product 134
- Underground quarries 134
- Relation of size of quarry to frequency of accidents 135

Petroleum industry 138
- Production 139
- Refining 140
- Over-all accident rate 140

Health of miners 142

Trend of fatal accidents in the mining industry 150

Résumé and conclusions 152

TABLES

		Page
1.	Foreign and United States accidental-death rates	8
2.	Accidental-death rates in the United States compared with coal-mine fatality rates, 1911-46	10
3.	Fatalities and fatality rates per million tons of coal mined, 1906-46	14
4.	Accident data for all coal mines (bituminous, anthracite and lignite)	16
5.	Tons of coal mined per fatal accident	17
6.	Fatal and nonfatal accidents at all coal mines	18
7.	Comparison of injury rates underground at all coal mines by principal causes, 1941-43	20
8.	Severity of injuries at coal mines	21
9.	Fatalities directly due to explosives underground	22
10.	Production of bituminous coal and lignite	24
11.	Employment data for bituminous-coal and lignite mines	24
12.	Number of accidents at bituminous-coal and lignite mines	25
13.	Accident rates based on millions of tons produced at bituminous-coal and lignite mines	26
14.	Man-hours of exposure in bituminous-coal and lignite mines	27
15.	Accident rates based on millions of man-hours of exposure at bituminous-coal and lignite mines	28
16.	Underground fatalities at bituminous-coal and lignite mines, by principal causes	33
17.	Fatal accidents due to falls of roof and coal in bituminous-coal and lignite mines	34
18.	Fatal accidents due to haulage in bituminous-coal and lignite mines	35
19.	Fatalities due to gas and coal-dust explosions	37
20.	Fatal accidents due to explosives	38
21.	Fatalities due to electricity underground	38
22.	Fatalities due to shaft accidents at bituminous-coal and lignite mines	40
23.	Coal-mine disasters in the United States in which five or more men were killed	41
24.	Major disasters in coal mines of the United States, 1906 to Dec. 31, 1947, inclusive	51
25.	Number of men killed in major disasters, by years and principal causes of the disasters, 1910-1946	53
26.	Fatalities due to major explosions and all other causes at underground bituminous-coal mines in the United States 1931-47, inclusive	56
27.	Accident rates per million tons of coal produced at underground bituminous-coal and lignite mines and surface plants	58
28.	Accident rates per million man-hours of exposure at bituminous-coal and lignite mines and the surface plants at underground mines	58
29.	Production of bituminous coal and lignite mines	59
30.	Employment data for bituminous-coal and lignite mines	60
31.	Number of accidents at bituminous-coal and lignite mines	61

TABLES (Cont'd.)

Page

32. Accident rates based upon millions of tons produced at bituminous-coal and lignite mines 61
33. Man-hours of exposure in bituminous-coal and lignite mines 62
34. Accident rates based upon millions of man-hours of exposure at bituminous-coal strippings 63
35. Fatal-accident data in bituminous-coal mines and in bituminous stripping operations 64
36. Twenty years of growth of mechanical loading at underground bituminous-coal and lignite mines 65
37. Percentage of bituminous-coal and lignite underground production mechanically loaded 66
38. Number of mechanical loading units in actual use 67
39. Summary of data for underground bituminous-coal mines in the United States using rock dust, 1930-43 68
40. Rock dusting in various States during 1943 69
41. Employment and accidents underground at bituminous-coal mines in the United States classified according to the thickness of the coal bed, 1943 71
42. Bituminous-coal and lignite mines classified by the number of employees underground 73
43. Comparative fatal-accident statistics, small mines, compared with total coal mines 74
44. Underground bituminous-coal and lignite mines classified by annual tonnage of coal mined 76
45. Age of employees in the mineral industry 78
46. Data on anthracite production and accident rates 82
47. Employment data for anthracite mines 83
48. Number of accidents at anthracite mines 84
49. Production of anthracite, in thousands of short tons 85
50. Man-hours of exposure at anthracite mines 85
51. Accident rates based upon millions of tons produced at anthracite mines 87
52. Accident rates based upon millions of man-hours of exposure at anthracite mines 87
53. Fatal accidents at anthracite mines, by principal causes. Rates based upon millions of tons 89
54. Fatal accidents at anthracite mines, by principal causes. Rates based upon millions of man-hours 89
55. Accident data for underground workings of anthracite mines 91
56. Accident data for anthracite strippings 93
57. Accident data for all noncoal mines in the United States, 1911-45.. 96
58. Accident rates per million man-hours for all mines except coal mines, 1931-45 97
59. Comparison of fatality rates per thousand 300-day workers in various branches of the metal and nonmetallic-mineral industries.. 97
60. Comparison of fatality rates per million man-hours in various branches of the metal and nonmetallic-mineral industries, 1931-46 99

TABLES (Cont'd.)

Page
61. Fatal accidents at underground metal mines, classified by principal causes, 1940-45 100
62. Accidents at copper mines in the United States, based upon millions of man-hours 103
63. Copper mines, employment and accident statistics, 1937-45 105
64. Accident data at iron mines in the United States, based upon millions of man-hours 106
65. Iron mines, employment and accident statistics, 1937-45 108
66. Accident data at lead-zinc mines in the Mississippi Valley States, based upon millions of man-hours 109
67. Lead and zinc mines (Mississippi Valley), employment and accident statistics, 1937-45 110
68. Accident data at gold, silver, and miscellaneous metal mine in the United States, based upon millions of man-hours 111
69. Gold, silver, and miscellaneous-metal mines, employment and accident statistics, 1937-45 112
70. Accident data at nonmetallic-mineral mines in the United States, 1911-42 113
71. Nonmetallic-mineral mines, employment and accident statistics, 1937-42 114
72. Accidents classified by mining methods, 1938-42 115
73. Employment and accident statistics for the quarrying and related industries, 1911-45 119
74. Injury rates per million man-hours at quarries and related industries, 1936-45 120
75. All quarries, severity of accidents, 1936-45 120
76. Open quarries, causes of fatal and nonfatal injuries, 1936-42 123
77. Underground quarries, causes of fatal and nonfatal injuries, 1936-42 124
78. Shafts or slopes at underground quarries, causes of fatal and nonfatal injuries, 1936-45 125
79. Employment and accident data classified by kind of quarry, 1940-45. 125
80. Accident-frequency rates per million man-hours, 1940-45 129
81. Accident-frequency rates for underground quarries, 1935-45 135
82. Accident-frequency data classified by the number of workers inside quarry, 1940-44 136
83. Employment and accident data in the drilling branch of the petroleum industry 138
84. Employment and accident data in the production branch of the petroleum industry 139
85. Employment and accident data of the refining branch of the petroleum industry 140
86. Employment and accident data for all branches of the petroleum industry 141

ILLUSTRATIONS

Fig.		Following page
1.	Number of men killed per million tons of coal produced in bituminous-coal and anthracite mines	12
2.	Number of men killed per million tons of coal produced in bituminous-coal and anthracite mines	12
3.	Fatalities from all causes in bituminous-coal and lignite mines	24
4.	Map of the United States showing general headquarters, field headquarters, district and subdistrict headquarters, location of mine safety stations and field offices, Health and Safety Division, Bureau of Mines	28
5.	Fatalities from roof and coal falls in bituminous-coal mines.	34
6.	Fatalities from haulage accidents in bituminous-coal mines...	34
7.	Fatalities from gas and coal-dust explosions in bituminous-coal mines	36
8.	Fatalities from explosives accidents in bituminous-coal mines	36
9.	Fatalities from electrical-contact accidents in bituminous-coal mines	36
10.	Number of major coal-mine disasters in the United States from 1906-1947	40
11.	Fatalities in metal and nonmetallic-mineral mines	94
12.	Fatalities per thousand 300-day workers in metal and nonmetallic-mineral mines	94
13.	Trend of fatal accidents at all coal mines, 1906-1946 (bituminous and anthracite)	150
14.	Trend of fatal accidents in all coal mines (bituminous and anthracite) based on millions of man hours	150
15.	Trend of fatal accidents, bituminous-coal and lignite mines, based upon millions of tons produced	150
16.	Trend of fatal accidents, bituminous-coal and lignite mines, based upon millions of man hours	150
17.	Trend of fatal accidents, underground bituminous-coal and lignite mines and surface plants, based upon millions of tons produced	150
18.	Trend of fatal accidents, bituminous-coal and lignite strippings	150
19.	Trend of fatal accidents, bituminous-coal and lignite strippings, based upon millions of man hours	150
20.	Trend of fatal accidents, anthracite mines, based upon millions of tons produced	150
21.	Trend of fatal accidents, anthracite mines, based upon millions of man hours	150
22.	Trend of fatal accidents, all mines except coal mines, based upon millions of man hours	150
23.	Trend of fatal accidents, copper mines, based upon millions of man hours	150
24.	Trend of fatal accidents, iron mines, based upon millions of man hours	152

ILLUSTRATIONS (Cont'd.)

Fig.		Following page
25.	Trend of fatal accidents, lead-zinc mines (Mississippi Valley), based upon millions of man hours	152
26.	Trend of fatal accidents, gold, silver and miscellaneous metal mines, based upon millions of man hours	152
27.	Trend of fatal accidents, nonmetallic-mineral mines, based upon millions of man hours	152
28.	Trend of fatal accidents, all quarries, based upon millions of man hours	152
29.	Trend of fatal accidents in certain branches of the quarrying industry, based upon millions of man hours	152

INTRODUCTION

The mining industry of the United States has long been severely criticized because of its high rate of accident occurrence, not only as compared with other industries of the United States but also with the mining industries of other countries, particularly Europe. Statistics, often not strictly comparable, indicate that the accident-frequency rate in all mining is currently about three times and the accident-severity rate is about seven times as great as the average for general industrial work in the United States. These figures are by no means comforting to humanitarian mining men, irrespective of their status in the industry, and they constitute a challenge that certainly cannot continue to be ignored much longer.

The picture becomes much darker when the above statistics are augmented with data indicating that on an exposure basis our mines (more particularly our coal mines) have accident rates two, three, or even more times as great as more or less similar mines in Europe, particularly England, Wales, Belgium, France, and Germany. The sting is alleviated to some extent by the knowledge that our coal mines produce about 4 to 5 times as much coal per man day as is produced in at least some European mines. However, all of these foreign accident statistics should be analyzed carefully before we become very much concerned about them, because they are not strictly comparable, for several reasons, not the least of which is the fact that foreign methods of compiling or recording accident statistics often differ materially from ours. Moreover, foreign mining and other conditions are definitely dissimilar to ours in many phases, and numerous other factors affect the comparability of foreign mine-accident statistics with those of the United States. Unquestionably, it should also be taken into consideration that the accident rate of the 140,000,000 or more constituting the populace of the United States as a whole is much higher than that of any other major country in the world and is two, three, or more times the rate of the European countries that have more favorable mine-accident rates than those of the United States (table 1). Moreover, it is significant that the mine-accident-severity rate of British mines is about six times the average accident-severity rate of the major industries of the British Isles, or but little more favorable than the comparable figures in the United States; namely, that mining has an accident severity rate about seven times the average of about 30 of the major industries of this country.

TABLE 1. - Foreign and United States accidental-death rates

Country	Latest year available	Deaths per 100,000 population	Country	Latest year available	Deaths per 100,000 population
Venezuela	1944	27.5	Estonia	1937	45.5
Peru	1943	29.0	Finland	1940	1/47.8
Greece	1938	29.2	New Zealand	1943	50.8
Ireland (Eire) ..	1943	29.3	Denmark	1944	52.0
Hungary	1941	29.5	Germany	1939	2/,4/52.1
Lithuania	1939	29.7	Un. of S. Africa	1939	5/53.2
Uruguay	1942	31.7	Switzerland	1943	6/54.9
Austria	1938	31.8	Spain	1944	55.0
Netherlands	1942	1/35.7	Norway	1941	1/55.1
Colombia	1940	36.1	Scotland	1943	1/55.9
Rumania	1939	37.2	France	1942	2/56.2
Portugal	1944	37.7	Canada	1945	1/56.6
No. Ireland	1943	2/38.4	Belgium	1944	57.9
Italy	1942	1/38.9	Argentina	1936	58.9
Guatemala	1943	40.0	Chile	1942	59.0
Sweden	1942	40.9	Mexico	1941	60.0
England and Wales	1938	41.8	UNITED STATES...	1945	1/72.7
Costa Rica	1942	42.4	Iceland	1940	77.6
Japan	1943	1/,3/44.1	Egypt	1943	116.1
Australia	1943	2/45.4			

1/ Excludes deaths due to operations of war.
2/ Includes deaths of military personnel.
3/ Rate based on Japanese only, but population apparently included Koreans, Formosans and foreigners.
4/ Includes Austria and the Sudentenland.
5/ Based on deaths and population of Europeans only.
6/ Includes homicides.
(Taken from Accident Facts, National Safety Council, 1947 issue.)

Notwithstanding the fairly prevalent belief, fostered largely by the loose use and equally loose interpretation of accident statistics of foreign countries as compared with ours (frequently not even reasonably comparable), that the mines of the United States are conducted with less regard to safety than in other countries, there is good reason to believe that safety of the workers is given at least as much consideration in our mines as in the mines of any other nation, and that those who are employed in and around our mines enjoy safety conditions and procedures as well as results comparable with those achieved in any other country.

It is still too soon after the war to obtain recent information on accidental-death rates for most countries. In some nations there was interference with the work of vital statistics agencies and lack of adequate medical services probably resulted in incomplete reporting of deaths during the war years.

However, prewar death rates appear so obsolete that it is desirable to change to more recent (if not entirely satisfactory) rates where possible.

The foregoing table gives the latest available data. The principal qualifications are stated in the footnotes, but space limitations do not permit a statement of every difference in methods of classification or inclusiveness.

Except where specified otherwise, the rates for war years include deaths of civilians and military personnel due to operations of war.

That the coal-mining industry has progressed in preventing accidents is evident from the fact that coal mining has reduced its fatality rate much faster and farther than the entire country has reduced its fatal-accident rate. In 1911 the fatality rate of the United States per 100,000 population was 84.7, and in 1946 the present estimate places the rate as 70.8, the 1946 rate being 16.4 percent lower than the 1911 rate. The coal mine-fatality rate in 1911 was 365 per 100,000 employed, and the estimated rate for 1946 is 213, or a reduction of 41.6 percent below the 1911 rate; hence, coal mining has reduced its fatality rate 2.7 times as much or as rapidly as has the entire country. On a fatality rate per million tons-produced basis, the percentage reduction is even greater, the fatality rate per million tons produced being 69.3 percent lower in 1946 than in 1911, the rate in 1911 being 5.35 fatalities per million tons of coal produced, and in 1946 it was 1.64. Evidently, the coal-mining industry over the past 36 years has progressed much more in the prevention of fatal accidents to its workers than the country at large has done in the prevention of fatal accidents to the populace at large (table 2).

Any type of mining is inherently more hazardous than most of the other major occupations, as the workers generally are employed underground and are subject to such risks as falls of ground, the use of explosives, poor lighting, handling moving machinery in cramped places, transportation difficulties analogous to those on our streets and highways, and often inadequate ventilation with explosive gases and dusts present. The tasks that must be performed in most industries must likewise be performed in mining under these as well as other adverse conditions, and the natural result is that mine accidents are more frequent and generally more severe than in other industries.

The accident statistics of the mining industry show conclusively that this industry is one of the most hazardous of all occupations notwithstanding the progress that has been made in accident prevention throughout the industry as a whole. The National Safety Council Accident statistics reveal the following relative standing of mining with other major industries in 1945:

Deaths and death rates of workers by major industries, 1945

Industry	Total deaths	Deaths per 100,000 workers
Mining, quarrying, oil and gas wells	1,500	187
Construction	1,700	126
Transportation	2,100	68
Agriculture	4,500	53
Public utilities	400	44
Service	2,300	20
Manufacturing	2,700	19
Trade	800	10

TABLE 2. - Accidental-death rates in United States, compared with coal-mine fatality rates, 1911-46

Year	Deaths per 100,000 population, United States	Percent increase (+) or decrease (-) from 1911 rate	Deaths per 100,000 employed in coal mines of United States	Percent increase (+) or decrease (-) from 1911 rate	Deaths per million tons of coal produced in United States	Percent increase (+) or decrease (-) from 1911 rate
1911	84.7	-	365	-	5.35	-
1912	-	-	335	- 8.22	4.53	-15.33
1913	85.5	+ 0.94	373	+ 2.19	4.89	- 8.60
1914	78.7	- 7.08	322	- 9.32	4.78	-10.65
1915	76.6	- 9.56	309	-15.34	4.27	-20.19
1916	84.2	- 0.59	309	-15.34	3.77	-29.53
1917	88.2	+ 4.13	356	- 2.47	4.14	-22.62
1918	82.3	- 2.83	338	- 7.40	3.80	-28.97
1919	71.9	-15.11	299	-18.02	4.19	-21.68
1920	71.4	-15.70	290	-20.55	3.45	-35.51
1921	68.7	-18.89	242	-33.70	3.94	-26.35
1922	70.0	-17.35	235	-35.62	4.16	-22.24
1923	76.4	- 9.80	285	-21.92	3.74	-30.09
1924	76.4	- 9.80	308	-15.62	4.29	-21.50
1925	78.3	- 7.55	298	-18.36	3.84	-28.22
1926	78.6	- 7.20	332	- 9.04	3.83	-28.41
1927	78.4	- 7.44	294	-19.45	3.73	-30.28
1928	79.2	- 6.49	319	-12.60	3.78	-29.35
1929	80.9	- 4.49	334	- 8.49	3.59	-32.90
1930	80.4	- 5.08	320	-12.33	3.84	-28.22

TABLE 2. - Accidental-death rates in United States, compared with coal-mine fatality rates, 1911-46 (Cont'd.)

Year	Deaths per 100,000 population, United States	Percent increase (+) or decrease (-) from 1911 rate	Deaths per 100,000 employed in coal mines of United States	Percent increase (+) or decrease (-) from 1911 rate	Deaths per million tons of coal produced in United States	Percent increase (+) or decrease (-) from 1911 rate
1931	78.6	- 7.20	248	-32.05	3.31	-38.13
1932	71.5	-15.58	229	-37.26	3.36	-37.20
1933	72.5	-14.40	203	-44.38	2.78	-48.03
1934	79.9	- 5.67	216	-40.82	2.94	-45.05
1935	78.4	- 7.43	220	-39.73	2.92	-45.42
1936	83.7	- 1.18	230	-36.99	2.73	-48.97
1937	81.4	- 3.90	240	-34.24	2.83	-47.10
1938	72.2	-14.75	204	-44.11	2.79	-47.85
1939	70.7	-16.53	200	-45.21	2.41	-54.95
1940	73.4	-13.34	260	-28.77	2.71	-49.35
1941	76.3	- 9.99	232	-36.44	2.22	-58.50
1942	71.7	-15.35	277	-24.11	2.30	-57.01
1943	73.9	-12.75	298	-18.36	2.22	-58.50
1944	71.8	-15.23	286	-21.64	1.90	-64.49
1945	72.7	-14.20	247	-32.33	1.71	-68.04
1946	1/70.8	-16.4	213	-41.64	1.64	-69.30

1/ Estimated.

The mining industry may be divided into three major categories for statistical purposes, namely, coal mining, metal and nonmetallic mining, and quarrying. Many of the same types of risks are involved in all of these, also each has its own hazards. These major divisions of the industry are discussed separately. The National Safety Council published the following accident statistics for these major divisions of mining and classified their standings with other industries for the year 1945:

Type of mining	Accident data			
	Frequency	Rank	Severity	Rank
Quarrying	9.83	10	1.33	23
Mining other than coal	25.83	34	5.58	39
Coal mining	63.06	39	11.94	40
All industries (average)	13.63	-	1.16	-

The accident statistics of the mining industry as a whole compare very unfavorably with similar statistics of other industries, yet inside the mining industry remarkable accident-free records have been established by individual mines that compare favorably with those established by other industries that are far less hazardous than mining.

The records of years of accident-free work established by some individual mines clearly indicate that the mining industry as a whole can continue the work of accident prevention to advantage and, with the exercise of enough continuous efficient effort, can make the mines of the United States far safer places for miners to work than at present. Records established by individual mining companies show that mining as a whole can be made comparable with other industries insofar as safety is concerned, provided suitable and definitely feasible effort is exerted and maintained.

This publication is intended to provide information relative to mine accidents and their causes and to show that progress has been made over a period of many years even though much remains to be done. The effects of new mining methods, mechanization, and other advances in mining are reflected in the statistics, which are shown on both a tonnage and man-hours of exposure basis, when both are obtainable, in order to provide pertinent available information.

ACKNOWLEDGMENT

The Accident Analysis Division of the Bureau of Mines has furnished most of the statistical information in this publication, and their assistance is gratefully acknowledged.

COAL MINING

Coal-mine workers encounter most of the risks of workers in other industries and, in addition, other hazards not found in other types of occupations, some of these being due to abnormal atmospheric environment because of dusts, gases, temperatures, humidities, etc., as well as unusual difficulties due to stratigraphical and other geological conditions. The natural result is that both the severity and the frequency of accidents in coal mines compare

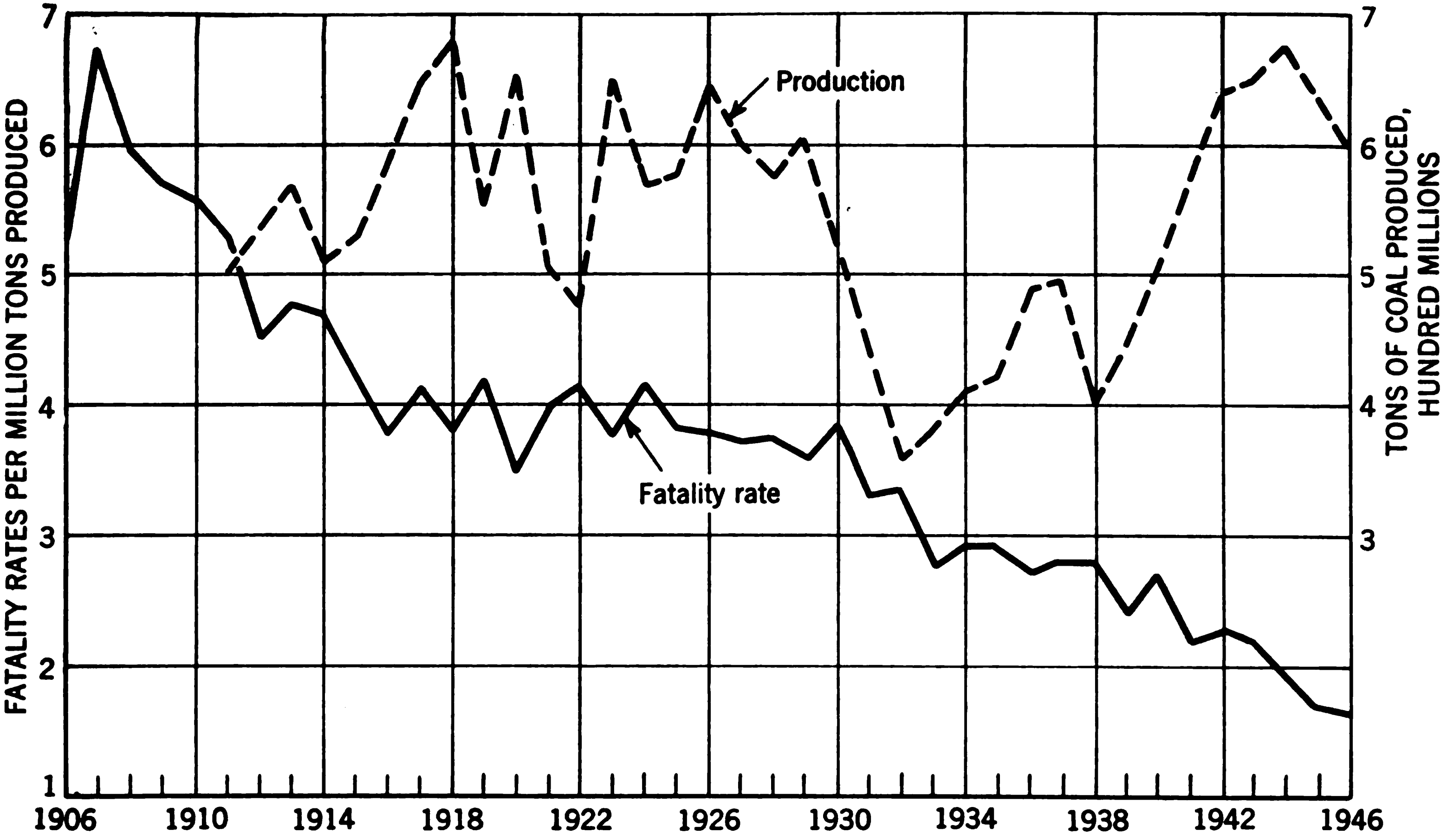

Figure 1. - Number of men killed per million tons of coal produced in bituminous-coal and anthracite mines.

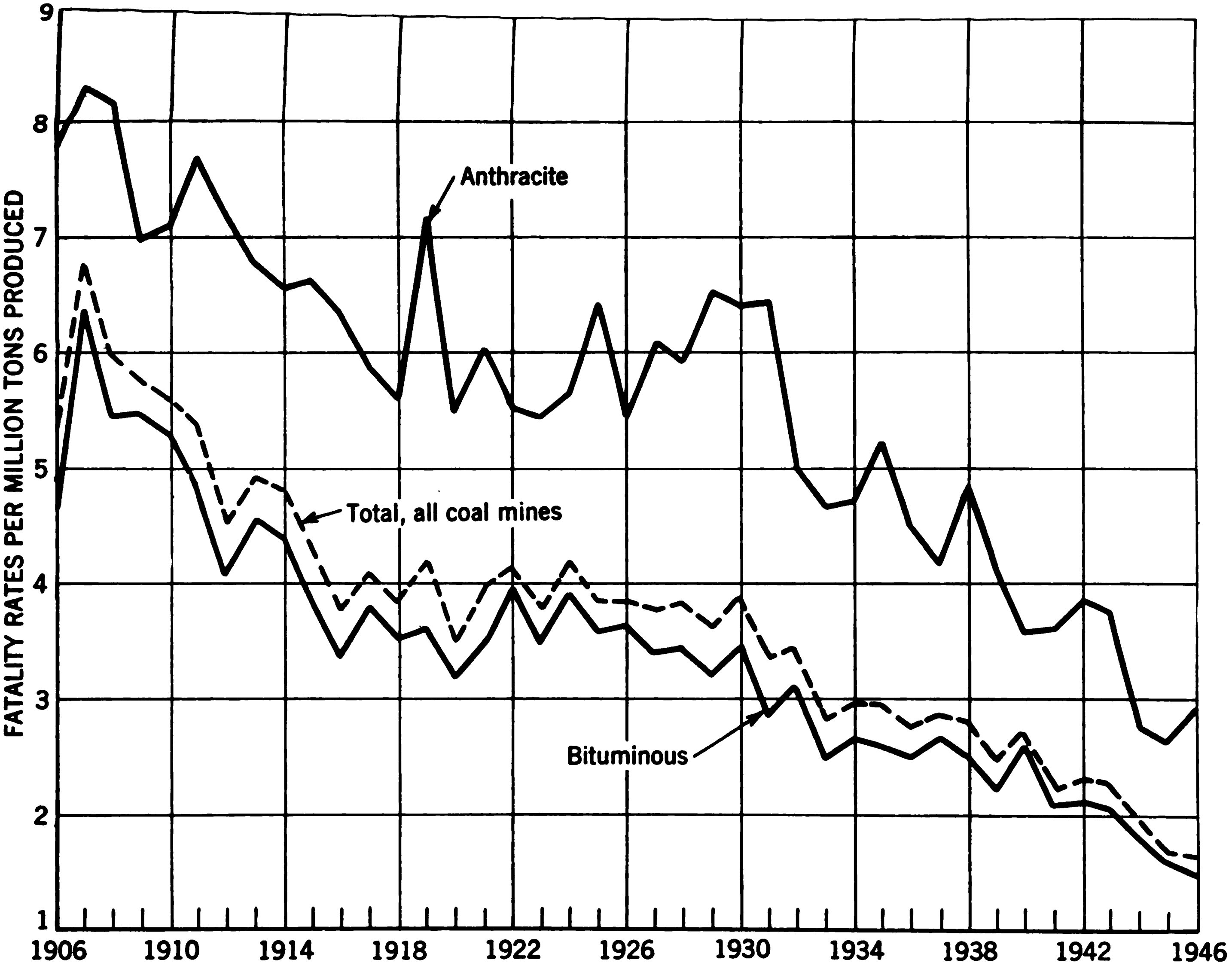

Figure 2. - Number of men killed per million tons of coal produced in bituminous-coal and anthracite mines.

unfavorably with other less hazardous industries, and relatively little is gained by contrasting the accident rates of coal mining with such occupations as those of the textile industry or automobile-manufacturing industry, etc., as the hazards involved are not comparable. In like manner, a comparison of accident statistics of coal mines of the United States with those of other large coal-producing nations has relatively little value or validity, because the conditions under which the coal is mined in those countries are usually entirely different, and the methods for compiling statistics are dissimilar to those in this country.

By comparing the statistics of coal mining in the United States over a long period, a relatively true picture is gained of the very definite progress that has been made in accident prevention by this vital industry; even so, in 1945 the statistics prepared by the National Safety Council revealed that the frequency of accidents in coal mining was exceeded, among the major occupations of the United States, only by the lumbering industry; the frequency rate for coal-mine accidents was 63.06 and that of lumbering was 64.65. The severity rate for coal-mine accidents in 1945 was 11.94, whereas the rate for mines other than coal was 5.57, and lumbering was 5.08. The average rates for all major industries of the United States was 13.63 for frequency and 1.16 for severity.

The real progress made in accident prevention in coal mines is clearly shown in table 3 and in figures 1 and 2. In 1907, 6.78 men were killed per million tons of coal mined, and by 1946 this appalling toll of life had been reduced to 1.64 men killed per million tons of coal mined; or, only 24 percent of the number of men killed in 1907 in producing one million tons of coal were killed in 1946. Some of the reduction in the number of fatal accidents per million tons mined is due to safer procedures and equipment, some to improved methods of mining and to mechanization of the mines, which increased the output per man-shift, and the increased percentage of open-cut coal has had a beneficial influence.

Another measure of the progress made in accident prevention in coal mining in the United States is shown by a comparison of the fatal-accident rates per million man-hours of exposure. The fatality rate per million man-hours in 1911 was 2.04, and by 1946 the rate was reduced to 1.13; hence, only 55.4 percent of the number of men killed per million man-hours of exposure in 1911 in coal mines were killed in 1946. Although statistics reveal that real progress has been made in the safety of coal mining, much remains to be done, for unquestionably the mines can be made much safer, and the number of fatal and nonfatal injuries can be reduced at least 50 percent, possibly as much as 75 percent, below what they now are; also, there is reason to believe that this reduction can be made without increase in production cost if both mine operators and mine workers handle the project in a reasonably cooperative manner without the bickering and rancor that has done much to retard progress in the past.

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TABLE 3. - Fatalities and fatality rates per million tons of coal mined, 1906-1946, inclusive

Year	Fatalities (anthracite plus bituminous coal)	Deaths per million tons of coal produced	Tonnage (anthracite plus bituminous coal)
1906	2,138	5.27	405,955,888
1907	3,242	6.78	477,892,536
1908	2,445	5.97	409,309,857
1909	2,642	5.73	460,807,263
1910	2,821	5.62	501,596,378
1911	2,656	5.35	496,371,126
1912	2,419	4.53	534,466,580
1913	2,785	4.89	570,084,125
1914	2,454	4.78	513,525,477
1915	2,269	4.27	531,619,487
1916	2,226	3.77	590,098,175
1917	2,696	4.14	651,402,374
1918	2,580	3.80	678,211,904
1919	2,323	4.19	553,952,259
1920	2,272	3.45	658,264,932
1921	1,995	3.94	506,395,401
1922	1,984	4.16	476,951,121
1923	2,462	3.74	657,903,671
1924	2,402	4.20	571,613,400
1925	2,234	3.84	581,869,890
1926	2,518	3.83	657,804,437
1927	2,231	3.73	597,858,916
1928	2,176	3.78	576,093,039
1929	2,187	3.59	608,816,788
1930	2,063	3.84	536,911,136
1931	1,463	3.31	441,750,978
1932	1,207	3.36	359,565,093
1933	1,064	2.78	383,171,877
1934	1,222	2.93	416,536,313
1935	1,242	2.925	424,632,005
1936	1,342	2.73	491,138,762
1937	1,413	2.83	498,792,928
1938	1,105	2.79	395,696,632
1939	1,078	2.41	447,976,639
1940	1,388	2.71	512,808,209
1941	1,266	2.222	569,884,209
1942	1,471	2.298	640,020,862
1943	1,451	2.222	652,977,029
1944	1,298	1.895	684,949,989
1945	1/1,079	1/1.706	2/632,290,894
1946	1/974	1/1.644	2/592,282,000

1/ Tentative, as estimated, 1947, by Accident Analysis Division, Bureau of Mines. These figures are likely to vary but slightly from the final figures, which will not be available for several months.

2/ From Coal Economics Division, Bureau of Mines.

Coal is one of the most important of all basic materials, not only in industry but in all phases of modern life; without it, many industries could not function, hence the welfare of this industry as a whole is of prime importance to the life of the entire country and, in fact, the entire world.

Coal technologists divide coal into three general classes - anthracite, bituminous-coal, and lignite, with many subdivisions - however, for the discussion of the status of safety in mining all coal is divided into two classes, (1) anthracite and (2) bituminous-coal and lignite. This is done primarily becuase the mining methods, the hazards, and the general conditions inherent to bituminous-coal and lignite mines are almost identical, whereas anthracite mines have numerous features not common to other coal mines.

Coal mining generally lends itself to modern mechanical methods of mining, and in recent years the tonnage of bituminous coal and lignite mined mechanically has attained great importance. Changes in mining methods, improved and new types of mining equipment, and greater knowledge of how to overcome some of the hazards of coal mining make it difficult to compare the results attained in any one year with the results attained in earlier years, especially prior to 1920; this is particularly true in accident statistics and the units used for comparisons. Before 1930, accident statistics in coal mining as compiled by the Bureau of Mines were obtained chiefly from the official reports of the various States; the records of fatal accidents were fairly accurate, but the nonfatal injury reports were incomplete or nonexistent. Beginning in 1930, the Bureau of Mines began assembling its own statistics of coal-mine accidents, both fatal and nonfatal. The reports of fatal accidents are now regarded as relatively accurate, as they must be reported to the proper State officials and are part of the vital statistics of each State; however, some States still obtain relatively little data from small mines. The status of nonfatal-injury reports is less certain; some mining companies report every injury as required by law, and others neglect to do so in some cases unless compensation payments are made or a hospital record is available. This is believed to be one of the many reasons for the wide fluctuations in nonfatal injury records and in data on a man-hour of exposure basis.

The tonnage of coal mined each year in the United States since 1910, the average number of workers employed, the number of fatal and nonfatal injuries, and the fatality rates based on millions of tons of coal produced and upon millions of man-hours of exposure are shown in table 4. The man-hours of exposure for 1910-29 were calculated from reports of the Coal Economics Branch of the Bureau of Mines, and from 1930 to the present they were compiled from company reports submitted to the Accident Statistics Division of the Bureau.

The employment of workers in coal mines has declined from 725,030 in 1910 to an estimated 437,000 in 1945 and 456,000 in 1946, a decrease of 39.7 and 37.2 percent, respectively. The largest average number of men was employed in coal mines in 1922, when 862,536 workers were reported, and the smallest number was the estimated 437,000 workers in 1945.

TABLE 4. - Accident data for all coal mines (bituminous, anthracite, and lignite

Year	Tons mined, in 1,000's of tons	Average number of workers	Injuries		Fatality rate	
			Fatal	Nonfatal	Per million tons	Per million man-hours
1910 ...	501,596	725,030	2,821		5,624	2,015
1911 ...	496,371	728,348	2,656		5,351	1,888
1912 ...	534,467	722,662	2,419		4,526	1,700
1913 ...	570,048	747,644	2,785		4,886	1,797
1914 ...	513,525	763,185	2,454		4,779	1,780
1915 ...	531,619	734,008	2,269		4,268	1,690
1916 ...	590,098	720,971	2,226		3,772	1,534
1917 ...	651,402	757,317	2,696		4,139	1,709
1918 ...	678,212	762,426	2,580		3,804	1,617
1919 ...	553,952	776,569	2,323		4,194	1,774
1920 ...	658,265	784,621	2,272		3,451	1,570
1921 ...	506,395	823,253	1,995		3,940	1,746
1922 ...	476,951	844,807	1,984		4,160	2,029
1923 ...	657,904	862,536	2,462		3,742	1,814
1924 ...	571,613	779,613	2,402		4,202	1,990
1925 ...	581,870	748,805	2,234		3,839	1,923
1926 ...	657,804	759,033	2,518		3,828	1,859
1927 ...	597,859	759,177	2,231		3,732	1,836
1928 ...	576,093	682,831	2,176		3,777	1,914
1929 ...	608,817	654,494	2,187		3,592	1,877
1930 ...	536,911	644,066	2,063	99,981	3,842	2,057
1931 ...	441,751	589,705	1,463	77,958	3,312	1,819
1932 ...	359,565	527,623	1,207	56,283	3,357	1,897
1933 ...	383,172	523,182	1,064	59,129	2,777	1,480
1934 ...	416,536	566,426	1,226	65,559	2,943	1,593
1935 ...	424,632	565,202	1,242	63,426	2,925	1,695
1936 ...	491,139	584,582	1,342	67,540	2,732	1,624
1937 ...	498,793	589,856	1,413	66,259	2,833	1,741
1938 ...	395,697	541,528	1,105	49,676	2,799	1,779
1939 ...	447,977	539,375	1,078	51,773	2,406	1,590
1940 ...	512,808	533,267	1,388	57,776	2,707	1,855
1941 ...	569,884	546,692	1,266	61,057	2,222	1,542
1942 ...	640,021	530,861	1,471	66,774	2,298	1,616
1943 ...	652,977	486,516	1,451	64,594	2,222	1,562
1944 ...	682,771	457,500	1,294	65,900	1,895	1,293
1945 ...	632,291	437,000	1,079	59,350	1,706	1,293
1946 ...	592,685	456,000	974	57,000	1,643	1,192

The annual production of coal has increased from 501,596,000 tons in 1910 to an estimated 592,685,000 tons in 1946; but during the period 1910-46 the two World Wars caused tremendous increases in coal production in certain years (1916-18 and 1942-45).

The fatal accidents in coal mines have declined from 2,821 in 1910 to an estimated 974 in 1946, or 65.3 percent. The fatality rates based on millions of tons of coal produced have declined from 5.624 in 1910 to 1.643 in 1946, or 70.8 percent. The fatality rate per million man-hours of exposure declined from 2.015 in 1919 to 1.192 in 1946, or 40.8 percent. If the fatality rates are converted to show the number of tons of coal mined for each worker killed, the results are impressive. Table 5 shows the number of tons of coal mined per fatal accident since 1910, at 5-year intervals and yearly since 1940.

TABLE 5. - Tons of coal mined per fatal accident

Year	Tonnage mined, 1,000's tons	Fatal accidents	Fatality rate per million tons	Tons of coal mined for each worker killed at coal mines
1910	501,596	2,821	5.624	177,800
1915	531,619	2,269	4.269	234,300
1920	658,265	2,272	3.451	289,770
1925	581,870	2,234	3.839	260,485
1930	536,911	2,063	3.842	260,300
1935	424,632	1,242	2.925	341,880
1940	512,808	1,388	2.707	369,400
1941	569,884	1,266	2.222	450,045
1942	640,021	1,471	2.298	435,161
1943	652,977	1,451	2.222	450,045
1944	682,771	1,294	1.895	527,704
1945	632,291	1,079	1.706	586,200
1946	592,685	974	1.643	608,600

Comparison of the 177,800 tons of coal mined for each man killed in 1910 with the record of 608,600 tons mined per fatality in 1946 is striking. It is incontrovertible that the coal produced in the United States in recent years was mined with the loss of far fewer lives than at any time in the history of coal mining in the United States, and this is the true measure of safety combined with efficiency. Continued progress in safety in coal mining can be expected, as, for example, the Chief of the Mine Inspection Department of the State of Pennsylvania reported that in the first 6 months of 1947 approximately 1,000,000 tons of coal was mined in that State for each fatal accident.

Classification of the causes of coal-mine accidents for the period 1939-44 is given in table 6. It should be noted that the two principal causes of fatal accidents in coal mining are falls of roof or face and haulage; in 1940 major explosions of gas or dust exceeded haulage as a cause of fatal accidents. The principal cuases of mine accidents are discussed separately in the chapters on anthracite mines and bituminous-coal and lignite mines.

TABLE 6. - Fatal and nonfatal accidents at all coal mines (anthracite, bituminous, and lignite)

	1939		1940		1941		1942		1943	
Underground	Killed	Nonfatal injuries	Killed	Nonfatal injuries	Killed	Nonfatal injuries	Killed	Nonfatal injuries	Killed	Nonfatal injuries
Falls of roof or face	621	13,507	625	14,524	674	15,190	724	15,890	704	12,686
Mine cars and locomotives.	182	9,755	228	10,900	218	11,570	278	13,447	263	12,966
Explosions of gas or dust:										
Local	18	208	21	338	31	269	30	186	19	128
Major	28		276		66		127		162	
Explosives	32	416	36	445	36	397	29	426	36	438
Electricity	51	785	37	878	47	831	57	1,072	35	1,072
Machinery	38	3,745	42	4,429	39	5,232	50	5,631	34	5,481
Mine fires		9	7	7	4	18	8	18	14	77
Miscellaneous	33	19,720	21	21,828	36	23,372	43	25,793	50	23,562
Shaft	11	116	15	130	15	109	7	108	10	149
Total underground ...	1,014	48,261	1,308	53,479	1,166	56,970	1,353	62,571	1,327	56,559
Strippings	16	1,316	27	1,512	40	1,651	35	1,622	39	1,861
Surface:										
Haulage	20	1,115	17	1,181	20	1,160	38	1,285	30	1,543
Machinery	5	480	12	590	14	537	17	543	17	657
Miscellaneous	23	2,843	24	3,019	26	3,147	28	3,543	38	3,974
Total surface	48	4,438	53	4,790	60	4,844	83	5,371	85	6,174
Grand total	1,078	54,015	1,388	59,781	1,266	63,465	1,471	69,564	1,451	64,594

Principal Causes of Accidents, All Coal Mines

The Bureau of Mines classifies all accidents that occur in bituminous-coal and lignite mines and anthracite mines as resulting from the same general principal causes, as the mines have essentially similar general over-all hazards, although anthracite mining is distinct from bituminous-coal and lignite mining in many of its hazards, mining methods, and general conditions.

Table 7 shows the underground injury rates per million man-hours of exposure for bituminous-coal and lignite mines, anthracite mines, and all coal mines classified according to the same principal causes. The difference in the hazards of the two classes of mines (anthracite and bituminous-coal) is clearly shown in the table. Falls of roof is the principal cause of fatal and nonfatal accidents at all coal mines, but "rush of coal, rock, or gob" is a much more serious hazard in anthracite mines than in bituminous-coal and lignite mines because a large part of the tonnage of anthracite is obtained from rather steeply dipping beds and much of the production is derived from extracting pillars on second or third mining.

Haulage creates approximately the same hazards in all coal mines and the rates indicate this. In anthracite mines, it is necessary to handle timber and other materials up to the working faces from the gangways, and this results in higher injury rates than when handling the same type of material in the flatter beds usually present in bituminous-coal and lignite mines. Similarily, there are numerous chutes and other openings with differences in level in anthracite mines, and "falls of persons" is an important cause of injury because of falling to a lower level.

The bituminous-coal and lignite mines are usually much more completely mechanized than anthracite mines, and as a result "machinery" is more important as a cause of injury in them than in anthracite mines.

A much larger amount of explosives is used in anthracite mines than in bituminous-coal and lignite mines of the same size; many rock tunnels are driven in anthracite mines and, chiefly because of the steep pitches, a large part of the coal is "shot from solid," requiring larger amounts of explosives than if the coal were cut before blasting. The more extensive use of explosives, as well as the greater difficulty in using them, is reflected in the injury rates due to explosives, which are several times higher in anthracite mines that at bituminous-coal and lignite mines.

Anthracite mines usually are gassy, but the dust is not considered to be explosive; although gas ignitions occur relatively frequently, the resultant explosion is not propagated by coal dust, as in bituminous mines, and the loss of life is lower than in bituminous mines. The fatalities from explosions of gas or coal dust are much higher in bituminous-coal and lignite mines than in anthracite mines, which reflects the effect of the much greater explosibility of bituminous coal dust than anthracite dust.

TABLE 7. - Comparison of injury rates underground at all coal mines by principal causes, 1941-43

	Fatal accident rates per million man-hours			Nonfatal accident rates per million man-hours		
	Bituminous coal and lignite	Anthracite	All coal	Bituminous coal and lignite	Anthracite	All coal
Falls of roof (rock, coal, slate):						
1941	1.007	.950	1.019	21.566	26.391	22.268
1942	.951	1.246	.991	20.962	25.070	22.042
1943	.961	.988	.965	17.156	18.298	17.323
Bush of coal, rock, or gob:						
1941	.012	.094	.024	.542	2.192	.781
1942	.002	.081	.013	.317	1.740	.513
1943	.008	.076	.018	.234	1.311	.393
Haulage:						
1941	.339	.282	.331	17.458	18.133	17.566
1942	.389	.372	.386	18.635	18.765	18.653
1943	.372	.342	.367	18.738	14.441	18.107
Handling materials:						
1941	.004	.031	.008	10.912	37.144	14.725
1942	.006	.020	.008	11.955	37.671	15.503
1943	.020	.029	.021	10.826	23.561	12.698
Hand tools:						
1941	.002	-	.002	5.303	15.628	6.804
1942	.006	-	.006	5.294	12.048	6.226
1943	.002	0.009	.003	5.474	11.362	6.340
Falls of persons:						
1941	.005	.031	.009	3.235	12.966	4.649
1942	.006	-	.006	3.192	11.595	4.351
1943	.002	0.047	.008	2.629	10.735	3.821
Machinery:						
1941	.069	-	.059	7.913	8.091	7.939
1942	.079	0.010	.069	7.902	7.241	7.811
1943	.051	.029	.047	8.136	4.855	7.654
Electricity:						
1941	.075	.052	.071	1.309	.981	1.261
1942	.082	.060	.079	1.498	1.418	1.487
1943	.054	.019	.049	1.637	.684	1.497
Explosives:						
1941	.043	.125	.055	.435	1.399	.575
1942	.026	.130	.040	.512	1.086	.591
1943	.044	.086	.050	.570	.855	.612
Explosions of gas or coal dust:						
1941	.158	.084	.147	.266	1.242	.408
1942	.238	.090	.218	.183	.724	.258
1943	.272	.143	.253	.154	.323	.179

Accurate statistics showing the relative severity of accidents are difficult to obtain, as the status of the severity often can be ascertained only after the compensation awards are given which sometimes requires several years for the final determination. Table 8 shows the relative severity of injuries at anthracite, bituminous-coal, and lignite mines and at all coal mines for the period 1941-43.

TABLE 8. - Severity of injuries at coal mines, rates based upon millions of man-hours of exposure

	Bituminous-coal and lignite mines		Anthracite		All coal	
	Number of injuries	Rate	Number of injuries	Rate	Number of injuries	Rate
Fatal:						
1941	1,072	1.551	194	1.491	1,266	1.542
1942	1,245	1.611	226	1.643	1,471	1.616
1943	1,225	1.575	226	1.498	1,451	1.562
Permanent total disability:1/						
1941	68	.098	5	.038	73	.089
1942	62	.080	3	.022	65	.071
1943	23	.030	3	.020	26	.028
Permanent partial disability:2/						
1941	1,964	2.842	144	1.107	2,108	2.567
1942	1,935	2.504	110	.800	2,045	2.246
1943	1,182	1.519	105	.696	1,287	1.386
Temporary (1 day or more):						
1941	44,605	64.547	16,679	128.194	61,284	74.631
1942	51,196	66.245	16,258	118.188	67,454	74.094
1943	49,862	64.092	13,419	88.967	63,281	68.132
Total nonfatal injuries:						
1941	46,637	67.487	16,828	129.339	63,465	77.287
1942	53,193	68.829	16,371	119.010	69,564	76.411
1943	51,067	65.641	13,527	89.683	64,594	69.545
Total, all injuries:						
1941	47,709	69.038	17,022	130.830	64,731	78.289
1942	54,438	70.440	16,597	120.653	71,035	78.027
1943	52,292	67.216	13,753	91.181	66,045	71.108

1/ Permanent total disability: The loss of or loss of use of both hands or both arms or both legs, both feet, both eyes, or any two thereof, or any injury (except death) that permanently and totally incapacitates the injured person from following any gainful occupation.

2/ Permanent partial disability: Loss of or loss of use of one foot, leg, hand, arm, or eye, or loss of part of bone of one of the foregoing, or loss or loss of use of one or more fingers or one great toe, or any two or more toes, or the permanent impairment of use of any part of the body.

Accidents Due to Explosives

Accidents due to explosives, excluding gas or coal-dust explosions caused by explosives, continue to be one of the major causes of fatal accidents in coal mines although over a long period of years the number of mine workers killed annually by explosives has been drastically reduced.

The intended action of all explosives is destructive and disruptive of adjacent materials; hence, all explosives are potentially dangerous, and every type of explosive, irrespective of its relative safety, should be handled, stored, and used with utmost care at all times and under all conditions. Safer explosives, better blasting practices, and the education of workers in the hazards of using explosives have all helpted to reduce accidents from this cause.

Statistics of fatal accidents directly due to explosives are shown in table 9 for anthracite mines, bituminous-coal mines, and the entire coal-mining industry.

TABLE 9. - Fatalities directly due to explosives underground

Year	Anthracite	Bituminous	Total
1917	55	55	110
1920	49	78	127
1925	53	49	102
1930	31	47	78
1931	25	15	40
1932	15	21	36
1933	10	24	34
1934	15	21	36
1935	19	31	50
1936	20	31	51
1937	14	31	45
1938	11	23	34
1939	17	15	32
1940	8	28	36
1941	12	24	36
1942	13	16	29
1943	9	27	36
1944	17	17	34
1945	9	25	34
1946	8	12	20

Note: This tabulation does not take into consideration fatalities in explosions of gas or dust initiated by explosives.

Only by the continuous education of the makers and users of explosives in the safe methods of manufacturing, handling, storing, and use of them, and the constant vigilance on the part of the supervisory personnel can accidents from explosives be reduced or nearly eliminated. Possibly, in the future some procedure will be evolved by which coal can be dislodged from the face without using such inherently dangerous materials as explosives.

The tabulation indicates that, as compared with the year 1917, when there were 55 fatalities from explosives in anthracite mines, there was a reduction of 85.5 percent in 1946, when there were 8 fatalities from the cause. The reduction in bituminous mines from 55 in 1917 to 12 in 1946, or 78.2 percent, is not quite so spectacular as with anthracite, but it also denotes gratifying progress. The reduction from 110 fatalities from explosives in the entire coal-mining industry in 1917 to 20 in 1946 or 81.8 percent certainly indicates remarkable progress; however, it must be remembered that these figures do not include fatalities from mine fires or explosions initiated by explosives. Unquestionably much of the reduction is due to the far greater precautionary measures taken in connection with explosives in coal mining during the past several years than were in effect in 1917 or 1916. However, the occurrence of two major explosion disasters in 1947, with loss of 119 lives, due to misuse of explosives indicates that much remains to be done to safeguard coal mine workers from the hazards of explosives.

BITUMINOUS COAL AND LIGNITE

The bituminous-coal and lignite deposits of the United States are mined by underground workings and stripping; the statistics of the industry are fairly comprehensive, and it is possible to obtain much information regarding mine accidents from them. The rapid increase in the production of coal by stripping in recent years makes it necessary, for accident-statistics purposes, to consider the tonnage mined by both methods as well as the combined tonnages; failure to consider the statistics of underground mines and strippings separately, as well as the total for the industry, in a study of mine safety would give erroneous conclusions. However, it is of utmost significance and importance, in considering the accident statistics of the bituminous-coal and lignite industry, that it should be remembered that over 1,000 fewer workers are now killed each year in mining coal than were killed in mining approximately the same or smaller tonnages 20 years or more ago.

The production of bituminous coal and lignite classified into underground workings and strippings is shown in table 10. Coal mined by stripping in 1930 was a distinctly minor factor in the coal production of the United States, as it amounted to only 4.3 percent of the total, but by 1945 and 1946 stripping operations produced approximately 19 percent of the total.

The number of workers employed by bituminous-coal and lignite mines from 1930 to 1946, inclusive, is shown in table 11. Total employment has declined from 493,202 in 1930 to an estimated 379,000 in 1946, a loss of 12.5 percent. Underground employment declined from 426,664 in 1930 to 318,776 in 1943, the last year for which definite statistics are available. This is a loss of 25.3 percent. Surface-plant employment remained fairly constant, showing an increase of 9.7 percent from 59,546 in 1930 to 65,315 in 1943. The increase is due, at least in part, to the increased number of mines with attached washing or cleaning plants.

TABLE 10. - Production of bituminous coal and lignite

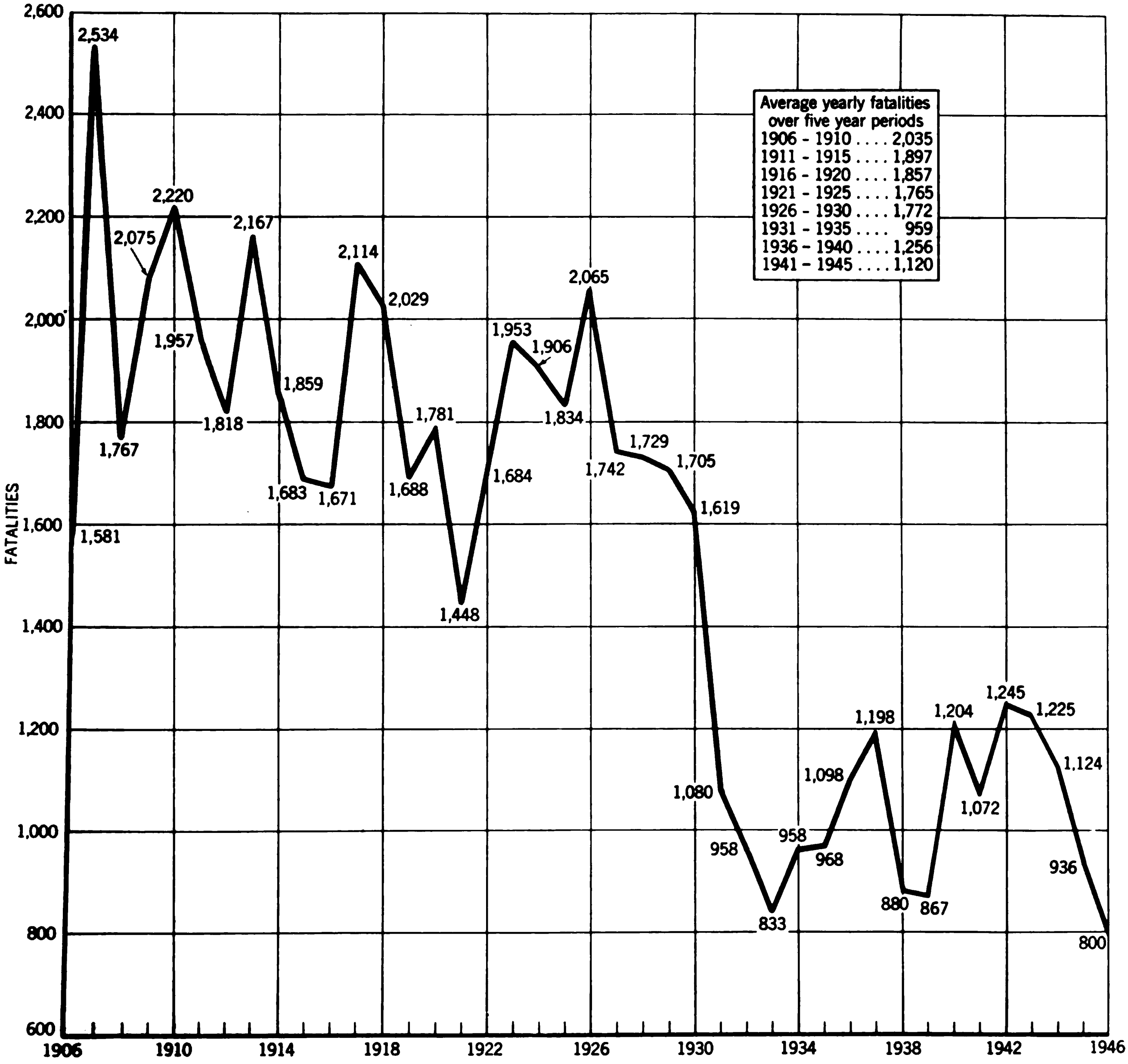
Year	Tonnage mined, in 1,000's of tons			Percentage of total production mined by stripping
	Underground workings	Stripping	Total	
1930	447,684	19,842	467,526	4.3
1931	363,254	18,849	382,105	4.9
1932	290,068	19,640	309,710	6.3
1933	315,394	18,237	333,631	5.5
1934	338,576	20,792	359,368	5.8
1935	348,722	23,647	372,369	6.4
1936	409,251	27,218	436,468	6.2
1937	415,425	31,622	447,047	7.1
1938	319,242	30,305	349,548	8.7
1939	359,371	37,260	396,631	9.4
1940	418,960	42,358	461,319	9.2
1941	460,292	55,478	515,769	10.7
1942	516,222	65,482	581,705	11.2
1943	513,651	79,821	593,471	13.5
1944	1/518,678	1/100,898	619,576	16.3
1945	1/467,630	1/109,987	1/577,617	1/19.0
1946	1/423,000	1/109,000	1/532,000	1/18.7

1/ From Coal Economics Division, Bureau of Mines.

TABLE 11. - Employment data for bituminous-coal and lignite mines

Year	Average number of workers employed			
	Underground workings	Stripping	Surface plants at underground mines	Total
1930	426,664	6,992	59,546	493,202
1931	387,693	6,259	56,322	450,274
1932	345,874	6,168	54,338	406,380
1933	352,915	7,058	58,779	418,752
1934	384,964	7,588	65,492	458,044
1935	389,978	8,493	63,883	462,354
1936	405,027	10,901	66,572	482,500
1937	413,136	11,695	65,940	490,771
1938	373,271	11,351	60,624	445,246
1939	370,791	12,848	61,405	445,044
1940	366,000	14,239	60,608	440,847
1941	374,953	18,605	64,186	457,744
1942	361,061	20,353	67,383	448,797
1943	318,776	23,044	65,315	407,135
1944	1/	1/	1/	3/380,000
1945	1/	2/33,569	1/	3/363,000
1946	1/	1/	1/	3/379,000

1/ Not yet available.
2/ Coal Economics Division, Bureau of Mines.
3/ Preliminary.



Average yearly fatalities over five year periods

1906 - 1910	2,035
1911 - 1915	1,897
1916 - 1920	1,857
1921 - 1925	1,765
1926 - 1930	1,772
1931 - 1935	959
1936 - 1940	1,256
1941 - 1945	1,120

Figure 3. - Fatalities from all causes in bituminous-coal mines.

The fatal and nonfatal accidents that occurred in the period 1930 to 1946, inclusive, are listed in table 12. The fatal accidents that occurred annually are shown in figure 3. The number of these accidents is subdivided into those occurring underground, at stripping operations, and in surface plants of underground mines.

TABLE 12. - Number of accidents at bituminous-coal and lignite mines

Year	Underground workings		Stripping		Surface plants at underground mines		Total	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	1,546	65,775	10	872	63	4,570	1,619	71,217
1931	1,026	50,286	2	594	52	3,095	1,080	53,975
1932	895	35,923	11	766	52	2,663	958	39,352
1933	772	40,052	9	856	52	3,038	853	43,946
1934	894	42,846	8	725	56	3,411	958	46,982
1935	905	43,666	14	735	49	3,128	968	47,529
1936	1,034	46,402	15	1,208	49	2,904	1,098	50,514
1937	1,128	48,268	8	1,275	62	3,304	1,198	52,847
1938	823	33,392	18	1,036	39	2,066	880	36,794
1939	823	34,822	9	1,133	35	2,589	867	38,544
1940	1,136	39,696	22	1,339	46	2,959	1,204	43,994
1941	994	42,218	34	1,450	44	2,969	1,072	46,637
1942	1,143	48,267	31	1,460	71	3,466	1,245	53,193
1943	1,130	45,035	33	1,531	62	4,501	1,225	51,067
1944	[1]1,051	[2]	[1]30	[2]	[1]39	[2]	[1]1,120	[1]52,900
1945	[1]854	[2]	[1]24	[2]	[1]58	[2]	[1]936	[1]47,750
1946	[1]734	[2]	[1]22	[2]	[1]44	[2]	[1]800	[1]44,000

[1] Preliminary.
[2] Not yet available.

The accident rates for fatal and nonfatal injuries, based upon millions of tons of coal mined, are shown in table 13. The total number of accidents is subdivided into those occurring in underground workings and in stripping operations. The statistics for underground workings include the injuries received at the surface plants of these mines. The fatal accident rate per million tons of coal produced from underground workings has dropped from a high of 3.453 in 1930 to an estimated 1.73 in 1946, and nonfatal injuries per million tons of coal mined have decreased from 146.923 in 1930 to an estimated 87.676 in 1946. The reduction in the rates for both the fatal and nonfatal injuries has been shown but the rates have been consistently downward in trend over the period.

TABLE 13. - Accident rates based on millions of tons produced at bituminous-coal and lignite mines

Year	Underground workings		Stripping		Total 1/	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	3.453	146,923	0.504	43.946	3.463	152.327
1931	2.824	138.432	.106	31.514	2.826	141.257
1932	3.085	123.843	.560	39.003	3.093	127.061
1933	2.448	126.991	.494	46.938	2.497	131.721
1934	2.640	126.548	.385	34.868	2.666	130.735
1935	2.595	125.217	.592	31.082	2.600	127.639
1936	2.527	113.383	.551	44.383	2.516	115.733
1937	2.715	116.189	.253	40.320	2.680	118.213
1938	2.578	105.537	.594	34.186	2.518	105.262
1939	2.290	96.897	.242	30.408	2.186	97.179
1940	2.711	94.749	.519	31.611	2.610	95.366
1941	2.160	91.720	.613	26.137	2.078	90.422
1942	2.214	93.500	.473	22.296	2.140	91.443
1943	2.200	87.676	.413	19.181	2.064	86.048
1944	2/2.020	3/	2/.297	3/	2/1.807	2/85.380
1945	2/1,800	3/	2/.219	3/	2/1.620	2/82.667
1946	2/1.730	3/	2/.201	3/	2/1.504	2/82.707

1/ Includes injuries to surface workers of underground mines as well as those injured in underground workings and in strip mines.

2/ Preliminary.

3/ Not yet available.

The rates for both fatal and nonfatal injuries per million tons of coal mined (total) in the period 1930 to 1946, inclusive, have been reduced from a high in 1930 of 3.463 for fatal and 152.327 for nonfatal injuries to an estimated 1.504 for fatalities and 82.707 for nonfatal injuries in 1946. The trend during the period has been consistently downward, with increases or decreases during individual years. The rates for underground mining and stripping operations are discussed later under those headings.

In table 14, the man-hours of exposure are shown in thousands of man-hours; the total is subdivided into underground workings, stripping operations, and surface plants at underground mines as before. The greatest changes in man-hours of exposure, percentagewise, occurred during the period 1930 to 1943, inclusive, in stripping and surface plants of underground mines; the man-hours worked in stripping has increased, roughly, four times and in surface plants about one-third.

TABLE 14. - Man-hours of exposure in bituminous-coal and lignite mines

Year	Man-hours worked in thousands of hours			
	Underground workings	Strippings	Surface plants at underground mines	Total
1930	647,986	10,238	91,925	750,149
1931	510,366	9,101	76,512	595,980
1932	404,182	8,853	66,413	479,447
1933	474,127	9,286	81,012	564,425
1934	496,437	9,347	85,275	591,059
1935	485,341	11,444	81,726	578,511
1936	559,734	15,134	95,033	669,901
1937	565,071	17,528	92,970	675,568
1938	417,345	16,309	71,662	505,316
1939	457,965	18,682	78,337	554,984
1940	516,346	22,128	87,500	625,974
1941	563,236	29,712	98,101	691,049
1942	621,472	34,988	116,369	772,829
1943	610,834	40,707	126,429	777,970
1944	1/	1/	1/	2/839,000
1945	1/	1/	1/	2/762,000
1946	1/	1/	1/	2/730,000

1/ Not yet available.
2/ Preliminary.

The fatal and nonfatal injury rates per million man-hours of exposure are shown in table 15. The total man-hours of exposure is subdivided into underground workings, surface plants at underground mines, and stripping, as in the case of the statistics based upon millions of tons of coal produced, and the fatal and nonfatal injury rates are shown by years. These statistics are discussed later under those headings.

Accidents in Coal Mines

The coal mining industry of the United States has been and still is wasteful of human life in comparison with other less hazardous occupations; there has been much discussion concerning methods of computing fatal-accident statistics of the coal-mining industry and the relative value of two much-used measuring sticks as a basis for comparison year by year, on one hand the fatality rate per million tons of coal mined, and on the other the rate per million man-hours of exposure. Irrespective of the method used in compiling accident rates, the fact remains that the number of men killed annually while engaged in mining coal has declined gradually through the years, and the tonnage of coal has increased materially at the same time that mine fatalities have definitely decreased.

TABLE 15. - Accident rates based on millions of man-hours of exposure at bituminous-coal and lignite mines

Year	Underground workings		Surface plants at underground mines		Stripping		Total	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	2.386	101.507	0.685	49.714	0.977	85.176	2.158	94.937
1931	2.010	98.529	.680	40.451	.220	65,270	1.812	90.565
1932	2.214	88.878	.763	40.098	1.243	86.527	1.998	82.078
1933	1.628	84.475	.642	37.501	.969	92.177	1.476	77.860
1934	1.801	86.307	.657	40.000	.856	77.566	1.621	79.488
1935	1.865	89.970	.600	38.274	1.223	64.228	1.673	82.157
1936	1.847	82.900	.516	30.558	.991	79.821	1.639	75.405
1937	1.996	85.419	.667	35.359	.456	72.741	1.773	78.226
1938	1.972	80.729	.554	28.830	1.104	63.523	1.741	72.814
1939	1.797	76.036	.447	33.049	.482	60.647	1.562	69.451
1940	2.200	76.879	.526	33.817	.994	60.512	1.923	70.281
1941	1.765	74.956	.449	30.265	1.144-	48.802	1.551	67.487
1942	1.839	77.666	.610	29.785	.886	41.729	1.611	68.829
1943	1.850	73.727	.490	35.601	.811	37.610	1.575	65.641
1944	1/	1/	1/	1/	2/.907	1/	2/1.334	2/63.051
1945	1/	1/	1/	1/	2/.420	1/	2/1.228	2/62.664
1946	1/	1/	1/	1/	1/	1/	1.190	65.070

1/ Not yet available.
2/ Estimated.

One of the most important functions of the Bureau of Mines is the forwarding of health and safety in the mining and allied industries. This work was authorized in the Organic Act of 1910 which created the Bureau of Mines, and the authorization was repeated and emphasized in the amended act of 1913; one of the dominating factors in the creation of the Bureau of Mines in 1910 was the fact that in the 5 years 1906 to 1910, inclusive, the coal mines of the United States had 84 major disasters with almost 2,500 fatalities. It was felt that the Federal Government was obligated to try to reduce this continual "bombardment" of approximately 17 major coal-mine disasters and 500 fatalities per year. That something has been done is proved by the fact that in the calender year 1946 there were two major coal-mine disasters with only 27 fatalities. In the calendar year 1933 there was one major disaster causing 7 deaths, and in the fiscal year 1938-39 there was not a major disaster in the coal mines of the United States.

The health and safety activities of the Bureau of Mines were begun immediately with the organization of the Bureau in July 1910 and have been continued consistently over the years. The beneficial effects of this work are widely acknowledged not only in the United States but also abroad.

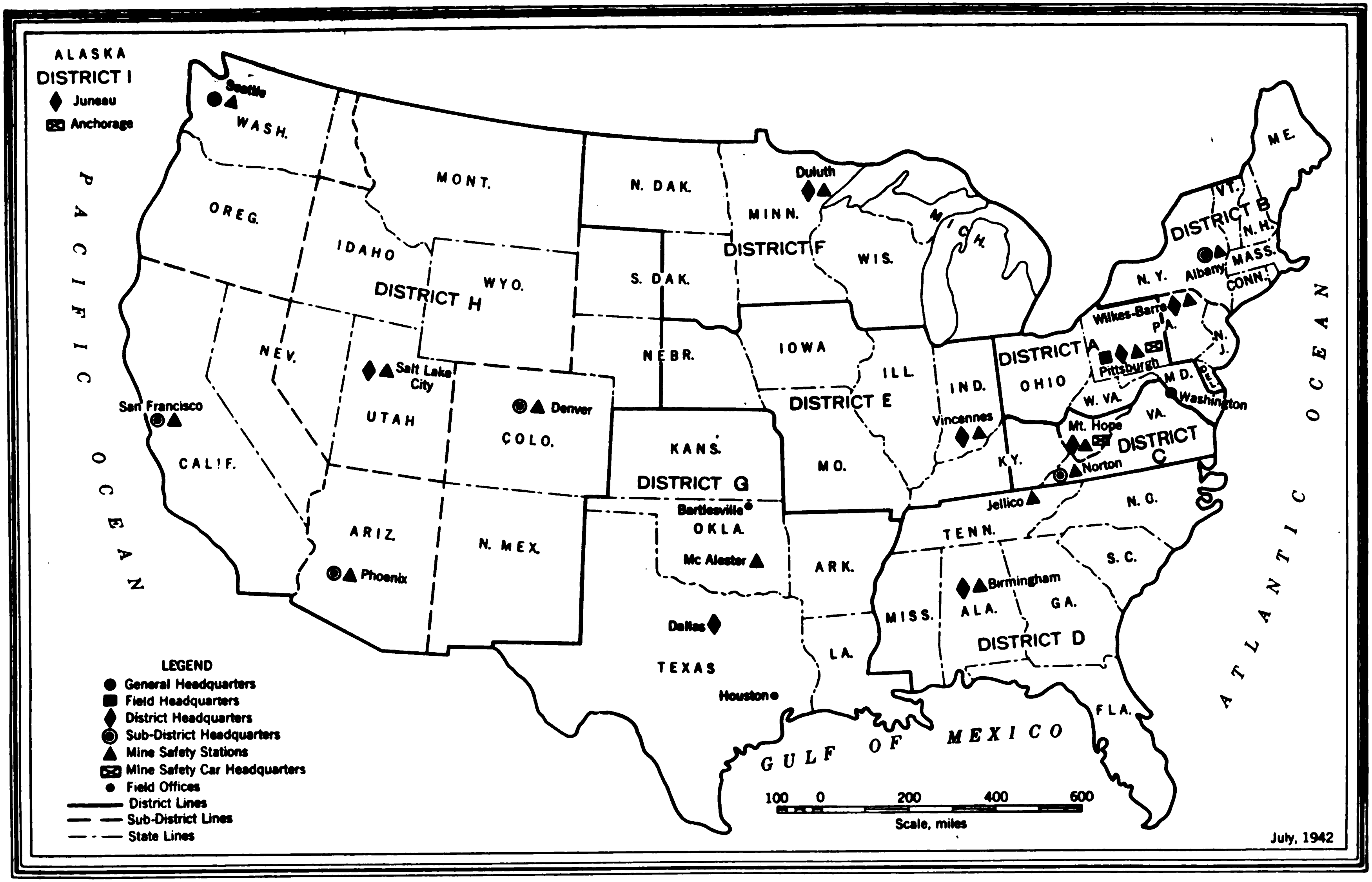


Figure 4. - Map of the United States showing general headquarters, field headquarters, districts, district and sub-district headquarters, location of mine safety stations and field offices, and headquarters of mine safety cars, safety and inspection divisions, Health and Safety Division, Bureau of Mines.

Those who have been engaged for any considerable time in the field activities of the Bureau of Mines in health and safety (fig. 4) have long known that nearly all matters pertaining to health, safety, and efficiency in the mineral industries are so inherently interlocked that any attempt to engage in any one without considering the others is almost certain to be ineffective, if not disastrous. Hence, Bureau of Mines employees in the Health and Safety Division are prone to associate all three of these phases of mining when any one is brought up for discussion or action; and most of the hundreds of health and safety pamphlets issued by the Bureau of Mines since its inception reflect this idea.

Mechanization of coal mines, begun early in the century but greatly accelerated during the past quarter of a century, has greatly increased the number of tons mined per man-shift but has also introduced numerous hazards that were not present when the coal was hand-loaded. These hazards have had to be studied and overcome in order to make our coal mines even reasonably safe. In a mechanized mine the workers are usually concentrated in a relatively small area and can have the benefits of better instruction and supervision than in a hand-loading mine, where the workers are scattered and adequate supervision is difficult to attain. This aids materially in taking measures to overcome the increased hazards due to mechanization, but it also makes it much more difficult to avoid the occurrence of major disasters (those in which five or more are killed), because the concentration of 5, 10, 20, or more workers in confined areas causes them to be in the path of gas or dust ignitions, roof falls, blasts from explosives, etc., which may cause relatively little property damage but large loss of life because of the heavy concentration of workers.

The gaging of coal-mine safety by calculating the number of fatal accidents that occur per million man-hours, although fundamentally sound in principle, has numerous features in actual application that largely nullify its accuracy as well as its usefulness. Proponents of this method of determining mine safety point out that a worker is exposed to underground hazards for a given number of hours irrespective of the type of mining or equipment used; therefore, the number of hours of exposure is the correct procedure with which to measure safety progress. It has always been difficult, in fact almost impossible, to obtain man-hour statistics that are anything like reliable insofar as coal mining is concerned, and this condition continues to exist. Workers frequently do not work anything like the required number of hours in a mine that is hand-loading coal, and the miner is paid on a tonnage basis, and under some conditions and in some places this also applies to mechanized mines. In many instances the miner loads his "turn" of a certain number of cars and leaves the mine (in many cases actually working only a few hours), but the full number of hours of work is credited to him for statistical purposes. Obviously, if a miner loads his "turn" in 3, 4, or 5 hours and leaves the mine (which is being and has been done to a considerable extent), he has not been exposed to the hazards of mining for 7, 8, or 9 hours, as the case may be, yet almost invariably he is credited with having worked the entire shift.

In hand-loading operations, especially in drift or slope mines where exit is available to employees at their pleasure, keeping anything like accurate data as to time spent in the mines is out of the question especially as regards contract miners or loaders. Moreover, even in mechanized mines operated on a contract basis, really accurate data as to man-hours worked or man-hours of exposures are by no means easy to obtain. However, with the increasing use of mechanized mining, with workers largely on a day-pay rather than a contract basis, man-hour data can be kept with a fair degree of accuracy. Hence, man-hour data are likely to become increasingly dependable with the increase of mechanization. When, however, the relatively much more nearly accurate data of the present or recent past as to accidents per thousand or per million man-hours of exposure are compared with the estimated or calculated similar data of 10, 20, 30, or more years ago, the results are so undependable as to be almost fantastic. Even today, very few coal-mining companies are equipped with time-clock or similar systems, which, if handled effectively, would give correct data as to man-hours, and very few, even when equipped with time clocks or systems, have the clerical organization required to assemble accurate data on man-hours. As to the past, man-hours must be calculated from such data as average number employed (itself a difficult figure to obtain) multiplied by the days the mine worked (which varies from mine to mine), and also multiplied by the hours worked per day (usually about 8, as most States have 8-hour laws, but in many mining regions, in the past as well as today, men worked 10, 12, 14, or more hours per day). Comparing these calculated or estimated figures of the past with the more nearly accurate data of the present is the acme of folly if there is a really sincere desire to obtain factual data as to the progress of safety in coal mining.

Calculating the progess of safety in coal mines by fatalities per million tons of coal mined also has unsatisfactory aspects; however, it is not difficult to obtain reasonably accurate data as to both tonnage of coal mined and number of fatal accidents that occur each year in coal mines; and, although mechanization has increased, the tonnage mined per manshift, even though additional hazards have been introduced, and also the considerable increase in the strip-mine tonnage has complicated the matter. Notwithstanding these as well other complications, comparisons of coal mine fatality rates on a tonnage basis are far more accurate than those on a man-hour-of-exposure basis, especially so when referring to figures prior to 1930, because any figures on man-hours of exposure for years prior to 1930 are the roughest kind of assumptions, and those subsequent to 1930 lack much of being anything like accurate. In this paper, statistics and accident rates are shown as calculated, both on a million-ton basis and a million-hour basis; however, in making comparisons with years prior to 1930, the per-million-ton basis is far more accurate, dependable, and informative than the man-hour-of-exposure basis.

In considering coal mining as a whole, the combined statistics of anthracite, bituminous coal, and lignite are used in table 2, and the fatalities for each are combined to give an over-all picture of the accident occurrence of the industry.

In the 41-year period 1906 to 1946, inclusive, the number of fatal accidents each year has varied widely, but over the period the number of deaths in the coal mines each year has decreased slowly but definitely. The worst year for fatal accidents in the period (as well as in the entire coal-mining history of the United States) was 1907, when 3,242 men were killed in the coal mines of the United States in producing about 478,000,000 tons of coal. The best year was 1946, when 974 lives were lost in the mines of the United States in producing about 592,000,000 tons of coal. The 1946 figures are tentative, but they are undoubtedly close to the final figures; this indicates that, as compared with 1907, coal-mining fatalities in 1946 decreased almost exactly 70 percent and output increased 24 percent. It now appears that 1946 is the first year in this century when fewer than 1,000 men were killed in American coal mines; since 1930 fewer than 2,000 men have been killed annually in the coal mines of the United States, and from 1906 to 1930 the number of men killed was consistently well above 2,000, and in some years above 3,000.

The annual coal production in the period 1906 to 1946, inclusive, ranged from 405,955,888 tons in 1906 to 684,949,989 tons in 1944, the largest ever attained in a single year in the United States. Deaths per million tons of coal produced ranged from 6.78 in 1907 to 1.644 in 1946, the latter the lowest fatality rate in the history of the industry.

The following data are significant in showing the improvement in coal-mine safety, insofar as fatal accidents are concerned, in two 3-year periods nearly 30 years apart, both years in which coal was urgently needed in the prosecution of world wars:

Year	Coal production, tons	Number of fatalities
1916	590,098,175	2,226
1917	651,402,374	2,696
1918	678,211,904	2,580
	1,919,712,453	7,502
1944	684,949,989	1,298
1945	632,290,894	1,079
1946	592,282,000	974
	1,909,522,883	3,351

These two 3-year periods represent the largest coal production that the industry has ever attained in any consecutive 3-year periods. The tonnage in each period is nearly the same, the difference being only 10,189,570 tons, but the number of men killed in producing coal in the latter period (1944-46) was much less than half the number killed in the 1916-18 period. The difference between 7,502 men killed in the 1916-18 period in mining virtually the same amount of coal as in the 1944-46 period, when 3,351 men were killed, is a saving of 4,151 lives for the coal-mining industry, and the country at large and the saving was made at a time when this country was confronted with the most critical shortage of man-power in the history of the United States. In both periods this country obtained maximum coal tonnage at a time when coal was desperately needed to handle war necessities, but in the period 1944-46 essentially the same tonnage was obtained as in the period 1916-18, with a saving of 4,151 lives (or 1,484 lives per year), reflecting very vividly the progress in safety in coal mining in the 30-year interval.

It is true that in the period 1944, 1945, and 1946, advantage was taken of greatly increased production of strip-mined coal and of the use of mechanized underground mining procedures, both of which were virtually unavailable in 1916, 1917, and 1918. That does not alter the fact that the coal-mining industry, through its own initiative and progressiveness, was able to provide the desperately needed coal of 3 years of the peak of the World War II and did it with the sacrifice of more than 4,000 fewer lives than would have been killed under procedures of 1916, 1917, and 1918, a saving of upwards of 1,300 coal miners lives per year at a time when manpower was desperately scarce. The coal-mining industry deserves great credit for this extremely patriotic performance.

Causes of Fatal Accidents in Underground Bituminous-coal and Lignite Mines

The causes of fatal accidents in bituminous-coal and lignite mines are classified by the Bureau of Mines into:

1. Falls of roof and coal
2. Haulage
3. Gas or dust explosions
4. Explosives
5. Electricity
6. Shaft
7. All other causes underground

Falls of roof and coal, haulage, and gas and dust explosions are the three principal causes of fatal accidents, and generally the numbers of persons killed annually by each cause fall in the same order. Table 16 lists the number of fatalities by each of these causes for the period 1906 to 1944, inclusive. The fatality rates, based on millions of man-hours of exposure and millions of tons of coal mined, are shown in the discussion of each of the major causes of accidents.

Falls of Roof and Coal

Falls of roof and coal is the principal cause of fatal accidents in bituminous-coal and lignite mines; in nearly every year since 1906 falls of roof and coal have caused more fatalities in underground mines than all other causes put together, including major disasters caused by gas or dust explosions.

Falls of roof and coal seldom result in a major disaster in which five or more men are killed, but the falls kill one or more persons at a time, and though they occur relatively frequently, very little publicity is given such accidents as compared with major explosion disasters; however, owing to the frequency of such falls, the number of workers killed annually from this single cause usually totals more than 50 percent of all underground fatalities, and in many years the number of fatalities from falls of roof and coal in coal mines aggregate 10 to 20 times as many as do fatalities from explosions of gas or dust, or both.

TABLE 16. - Underground fatalities at bituminous-coal and lignite mines, by principal causes

Year	Falls of roof and coal	Haulage	Gas or dust explosions	Explosives	Electricity	All other underground	Shaft	Total
1906	826	192	219	115	52	27	73	1,504
1907	911	260	911	134	49	99	59	2,423
1908	829	229	320	109	53	97	53	1,690
1909	975	240	264	122	52	312	37	2,002
1910	1,061	295	477	113	76	46	60	2,128
1911	1,007	294	331	72	92	44	31	1,871
1912	943	296	255	70	75	44	39	1,722
1913	1,007	344	464	63	79	82	32	2,071
1914	903	309	305	56	86	55	41	1,755
1915	818	269	270	76	85	35	30	1,583
1916	850	330	183	60	81	49	34	1,587
1917	965	433	319	55	76	60	44	1,952
1918	1,052	446	103	85	77	76	41	1,880
1919	878	310	149	57	64	79	39	1,576
1920	937	342	124	82	70	72	34	1,661
1921	782	275	62	74	76	71	25	1,365
1922	780	286	298	55	71	56	36	1,582
1923	948	347	330	66	70	64	31	1,856
1924	846	299	486	46	72	56	17	1,822
1925	910	310	302	49	80	76	30	1,757
1926	994	384	373	46	94	62	27	1,980
1927	924	309	187	48	94	70	22	1,654
1928	825	313	347	41	82	54	13	1,675
1929	922	349	168	45	75	56	17	1,632
1930	856	285	234	31	63	68	9	1,546
1931	624	194	68	15	62	44	19	1,026
1932	466	146	162	21	42	45	13	895
1933	458	162	27	24	46	45	10	772
1934	539	168	40	21	53	64	9	894
1935	524	198	26	31	43	70	13	905
1936	624	202	41	31	44	81	11	1,034
1937	606	244	116	31	52	64	15	1,128
1938	474	142	84	23	38	53	9	823
1939	500	155	43	15	49	56	5	823
1940	520	192	292	28	30	62	12	1,136
1941	574	191	89	24	42	65	9	994
1942	592	241	148	16	51	89	6	1,143
1943	592	227	166	27	33	80	5	1,130
1944	563	221	32	19	26	136	28	1,015

The number of workers killed by falls of roof and coal is shown in table 17, and although the number of persons killed annually from this cause has fallen from a high of 1,061 workers in 1910 and 1,007 in 1911 to 574 in 1911 and 592 in 1942, the percentage of fatalities from this cause, as compared to total underground fatalities, has remained nearly constant, due to the fact that in general, fall of roof accidents and the other causes of accidents have decreased almost at the same rates.

Many progressive mining companies have timbering rules requiring the miner to set timber in accordance with a predetermined plan rather than according to the individual miner's judgment; in some mines the enforcement of a uniform timbering plan has resulted in stopping or at least greatly reducing accidents from this cause, and it is believed that if this practice is adopted uniformly and enforced rigidly the accidents due to falls of roof and coal can be greatly reduced, though it is improbable that they can be eliminated.

The fatality rates for bituminous-coal and lignite mines, based upon millions of tons mined and upon millions of man-hours for the period 1930 to 1944, inclusive, are shown in table 17.

TABLE 17. - Fatal accidents due to falls of roof and coal

Year	Tons mined, 1,000's of tons	Fatal accidents	Fatality rates per million tons	Fatality rates per million man-hours
1930	447,684	856	1.923	1.321
1931	363,254	624	1.715	1.223
1932	290,068	466	1.605	1.153
1933	315,394	458	1.451	.966
1934	338,576	539	1.591	1.086
1935	348,722	524	1.502	1.080
1936	409,251	624	1.523	1.115
1937	415,425	606	1.458	1.072
1938	319,242	474	1.484	1.136
1939	359,371	500	1.391	1.092
1940	418,960	520	1.241	1.007
1941	460,292	574	1.245	1.019
1942	516,222	592	1.145	.953
1943	513,651	592	1.153	.969
1944	519,972	563	1.083	.882

It is probable that the fatality rate per million tons of coal mined more closely represents the true situation than the fatality rate per million man-haours; the total number of men killed by falls of roof and coal has been reduced materially, as shown in table 17 and figure 5, and this has occurred in the face of considerably increased production. A study of the fatality rate per million man-hours indicates that little if any progress has been made in reducing the number of fatal accidents from falls of roof and coal as the rate has remained substantially the same, but the number of deaths has dropped heavily, and this is brought out vividly in figure 5 and there is good reason to believe that the per million-ton rate is far more nearly accurate than the rate per million man-hours and that it also gives a much more dependable picture of the actual progress.

It is obvious from a study of these statistics that falls of roof and coal continue to be a prolific source of fatalities at underground.

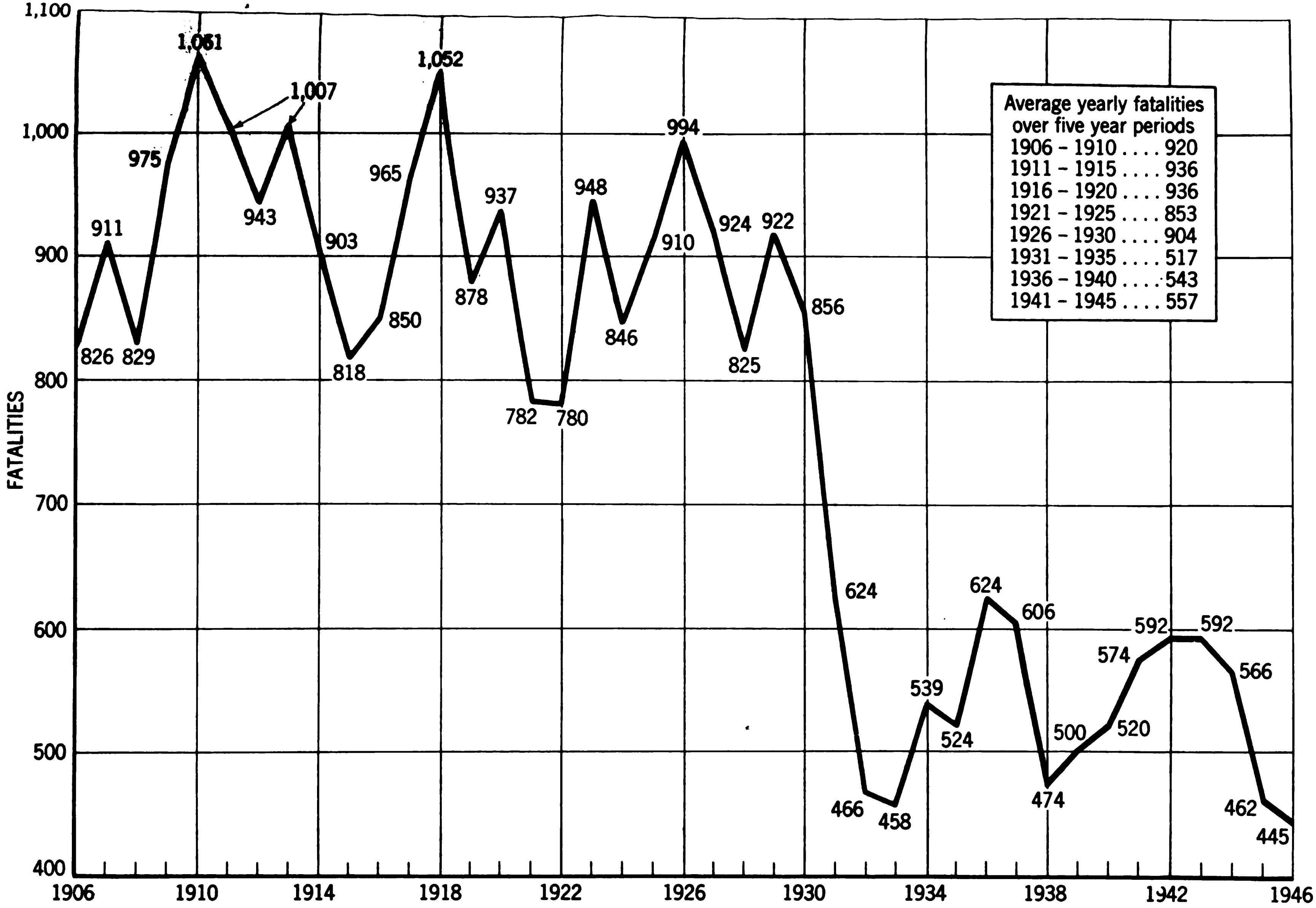


Figure 5. - Fatalities from roof and coal falls in bituminous-coal mines.

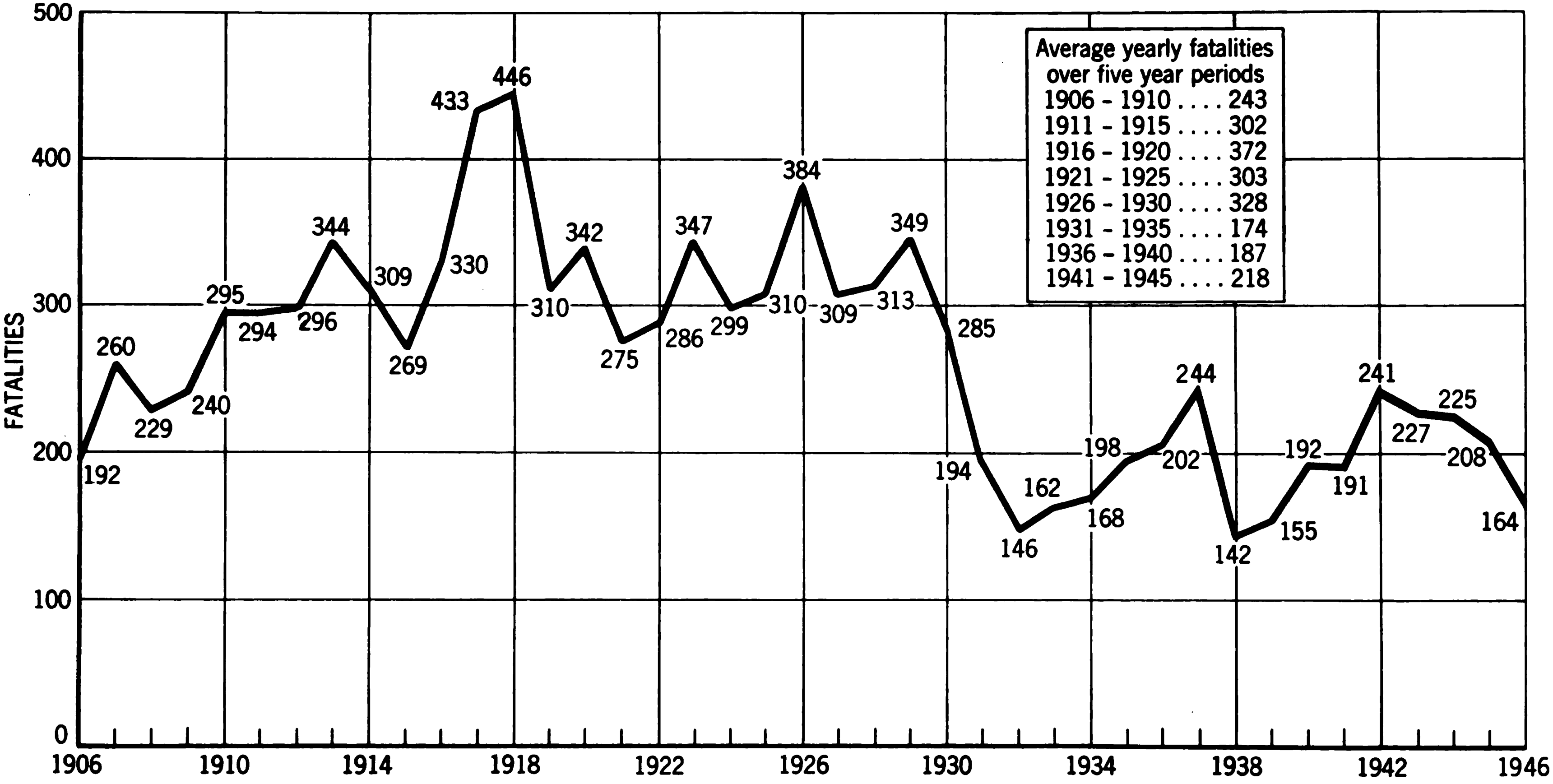


Figure 6. - Fatalities from haulage accidents in bituminous-coal mines.

bituminous-coal and lignite mines; the number of men killed each year and the high fatality rate as calculated by a base of millions of tons and millions of man-hours of exposure show that more intensive consideration should be given to the prevention of accidents from this cause. The reduction of accidents from this cause by closer attention to roof and rib conditions appears to be feasible, and if done it will be a quick and relatively inexpensive way of reducing the tremendous toll of human life that is still taken each year in coal mining; this requires much closer cooperation between workers and management than has been obtained heretofore, and if this cooperation is achieved it will do more than anything else to reduce this cause of coal-mine accidents at least 50 percent, which should be attainable.

Haulage

Haulage at underground bituminous-coal and lignite mines is the second main cause of fatal accidents in point of numbers of workers killed annually. Haulage accidents kill approximately one-third as many persons as are fatally injured by falls of roof and coal; and they cause almost one-fifth of the total fatalities in underground bituminous-coal mines year by year.

The number of persons killed annually in haulage accidents in the period 1906 to 1944, inclusive, is shown in table 18 and figure 6. The number of persons fatally injured annually from this cause has definitely decreased during the period, but the number killed annually varied considerably from a high of 446 in 1918 to a low of 142 in 1938.

TABLE 18. - Fatal accidents due to haulage in bituminous-coal and lignite mines

Year	Tons mined 1,000's of tons	Number of fatal accidents	Fatality rate per million tons	Fatality rate per million man-hours
1930	447,684	285	0.636	0.440
1931	363,254	194	.534	.380
1932	290,068	146	.503	.361
1933	315,394	162	.514	.342
1934	338,576	168	.497	.338
1935	348,722	198	.518	.408
1936	409,251	202	.493	.361
1937	415,425	244	.588	.432
1938	319,242	142	.444	.340
1939	359,371	155	.431	.338
1940	418,960	192	.458	.372
1941	460,292	191	.415	.339
1942	516,222	241	.467	.388
1943	513,651	227	.442	.372
1944	519,972	221	.425	.346

The principal causes of fatal haulage accidents, as reported, include being struck, run over, or squeezed between cars and locomotive; coupling, switching, or riding trips, or squeezed between the cars and the rib or timber or roof; in numerous instances the original cause is coming in contact with the trolley wire and then falling under cars or locomotives or being squeezed between the rib and cars or locomotives.

The fatality rates per million tons of coal mined and per million man-hours of exposure are also shown in table 18.

The need for improved haulage practice underground is plainly shown by a study of the fatality rates from this cause of injure; haulage has been consistently the second main cause of fatal accidents at underground bituminous-coal and lignite mines in nearly every year since 1906. It should be noted that considerably more men were killed in haulage accidents in the period 1906 to 1929 than were killed in the period 1930 to 1944. The problem of reducing haulage accidents is as difficult in our coal mines as it is on the streets and highways of the United States. In general, it is one of personal carelessness or foolhardiness.

Gas or Dust Explosions

Explosions of gas or dust are the third main cause of fatalities in bituminous-coal and lignite mines. Such accidents are sensational and usually are given wider publicity than accidents from any other cause or in any other industry. Explosions that result in the death of five or more workers are termed "major disasters" by the Bureau of Mines, and these are discussed under the heading "major coal-mine disasters."

Many explosions of gas or coal dust result in the death of fewer than five workers, and in some years the total number of workers killed in explosions causing fewer than five fatalities outnumber the fatalities caused by major explosions.

Table 19 and figure 7 list the number of persons killed in gas or dust explosions in the period 1906 to 1944. The fatality rates, based upon millions of tons of coal mined and millions of man-hours of exposure are shown in table 19.

The 4-year period 1933-36, inclusive, had the lowest fatality rates from gas and dust explosions ever attained by the bituminous-coal industry.

Explosives

The number of fatalities resulting annually from the use of explosives in underground bituminous-coal and lignite mines has been reduced considerably during the period 1906-44, inclusive (fig. 8). The safe methods of use, handling, and storage of explosives in mines have been widely publicized, and the workers have been given better instruction in explosives practice than formerly; the result of this plus the manufacture of safer types of explosives

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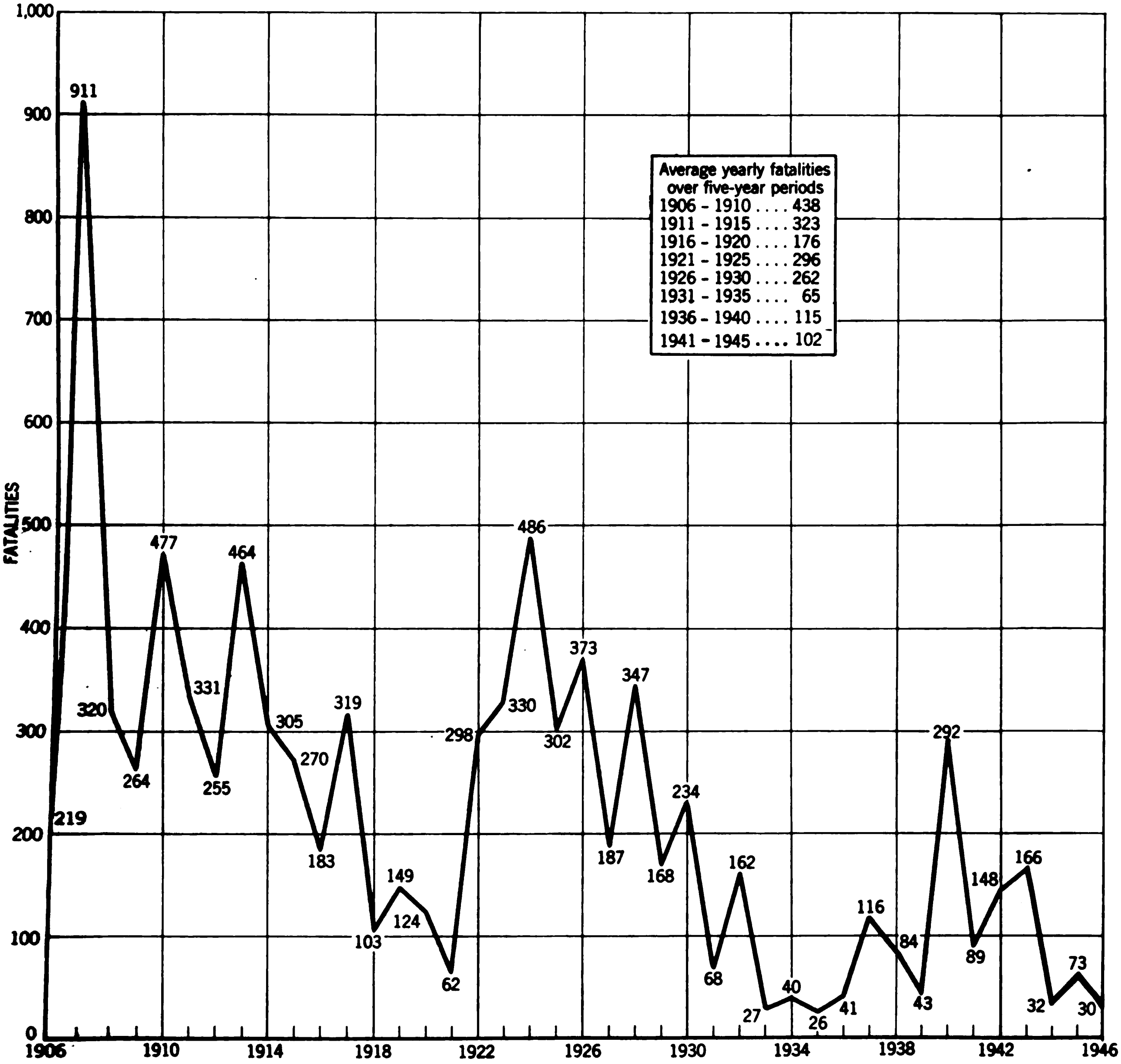

Figure 7. - Fatalities from gas and coal-dust explosions in bituminous-coal mines.

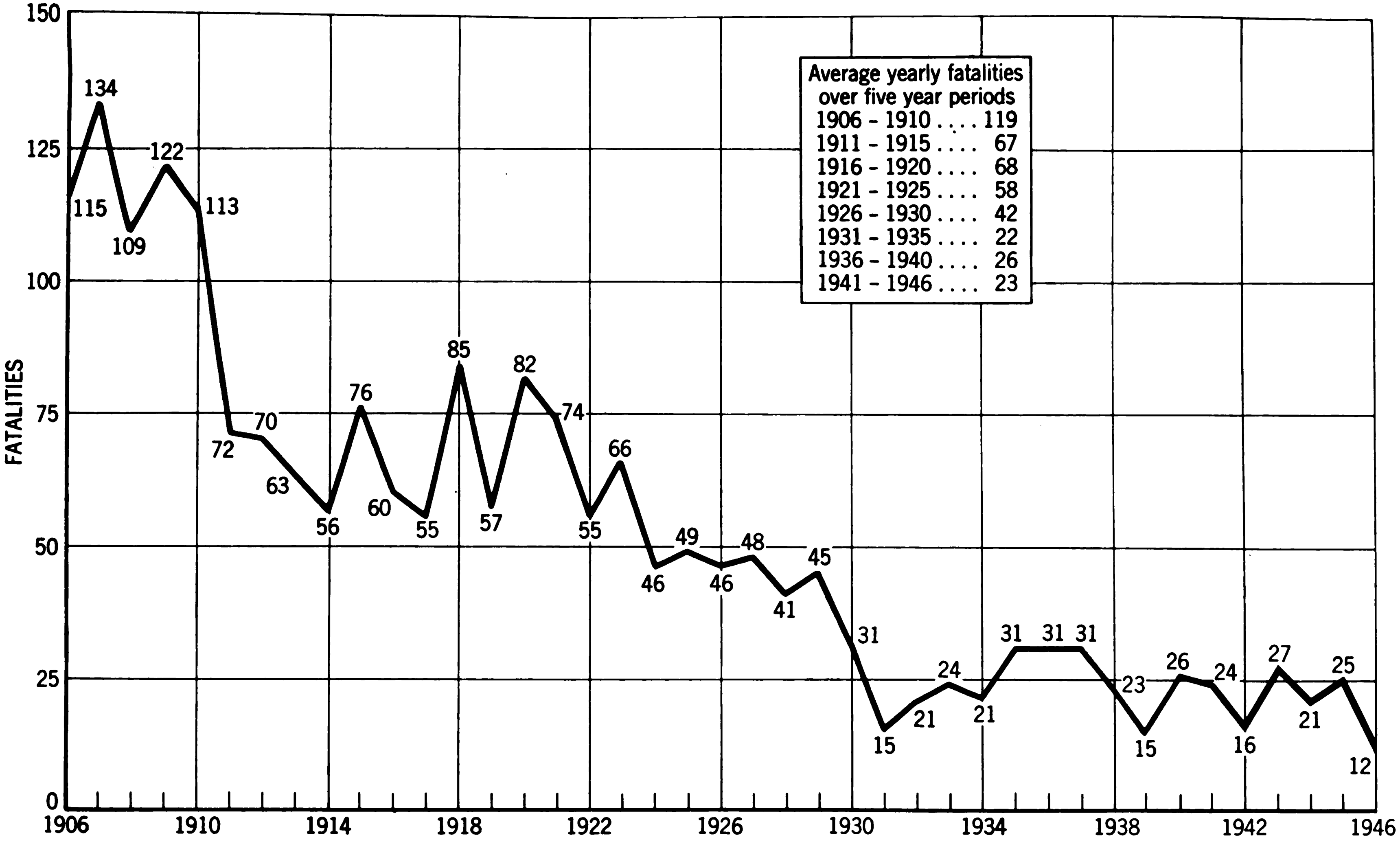

Figure 8. - Fatalities from explosives accidents in bituminous-coal mines.

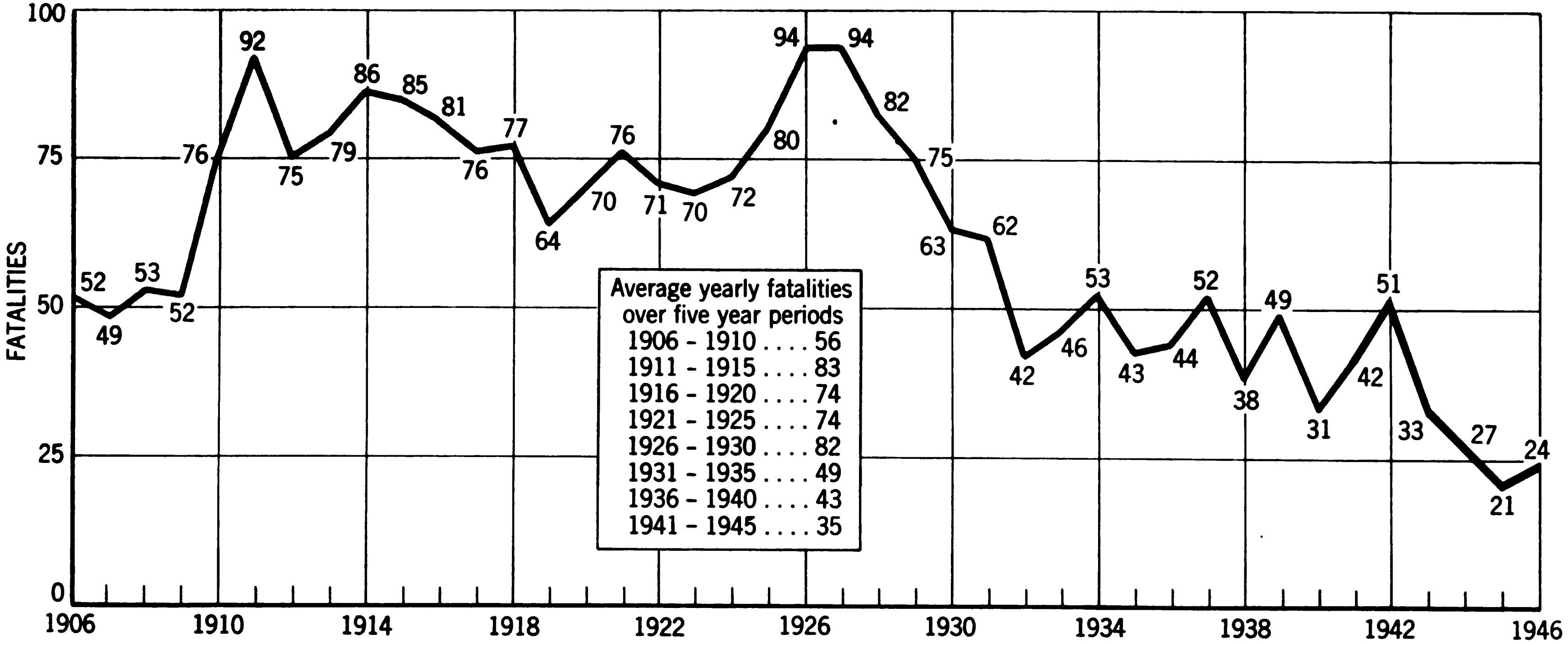

Figure 9. - Fatalities from electrical contact accidents in bituminous-coal mines. Note: This graph does not include data on fatal accidents from fires or explosions due to ignitions of gas or dust (or both), nor does it include accidents in which workers come in contact with electricity and immediately afterwards suffered death by haulage equipment, machinery, etc.

brought about a much better accident record from the use of explosives in recent years than early in the century. The fatal-accident rates due to explosives in the bituminous-coal industry per million man-hours for the 5-year period 1906 to 1910, inclusive, was 0.1446, which compares with 0.043 in 1941 and 0.026 in 1942.

TABLE 19. - Fatalities due to gas and dust explosions

Year	Tons mined, 1,000's of tons	Number of fatalities	Fatality rate	
			Per million tons	Per million man-hours
1930	447,684	234	0.524	0.361
1931	363,254	68	.187	.133
1932	290,068	162	.558	.401
1933	315,394	27	.086	.057
1934	338,576	40	.118	.081
1935	348,722	26	.075	.054
1936	409,251	41	.101	.073
1937	415,425	116	.279	.205
1938	319,242	84	.263	.201
1939	359,371	43	.119	.094
1940	418,960	292	.697	.566
1941	460,292	89	.193	.158
1942	516,222	148	.286	.238
1943	513,651	166	.323	.272
1944	519,972	32	.062	.050

The decreased use of black powder and the increased use of permissible explosives in underground mining have contributed much to the lowered fatality record. Improved explosives, blasting equipment, and the expansion in the use of electric blasting have all helped in the reduction in the number of blasting accidents.

Fatality rates from use of explosives, based upon millions of tons mined and upon millions of man-hours of exposure, are shown in table 20. However, the table does not take into consideration the heavy toll from explosions and fires initiated by explosives.

Fatal Accidents Caused by Electricity

Statistics relative to the fatal accidents in underground mines caused by electricity do not truly represent the progress that has been made in decreasing the electrical hazards underground. The number of workers killed each year by direct contact with electricity in the period 1906 to 1944 is shown in table 21 and figure 9; these figures do not include the very considerable number of fatalities in bituminous-coal mines due to fires or explosions caused by ignition of gas or dust (or both) by electricity.

The use of electricity in underground bituminous-coal and lignite mines has increased tremendously in the period since 1906, and many more workers are exposed to electrical hazards than heretofore. Definite hazards are bound to be present if electricity is taken underground. Electricity definitely promotes efficiency, but unless carefully installed, used, and maintained its presence in mines is likely to increase rather than reduce accidents.

TABLE 20. - Fatal accidents due to explosives

Year	Tons mined, 1,000's of tons	Fatal accidents	Fatality rates	
			Per million tons	Per million man-hours
1930	447,684	31	0.069	0.048
1931	303,254	15	.041	.029
1932	290,068	21	.072	.052
1933	315,394	24	.076	.050
1934	338,576	21	.062	.042
1935	348,722	31	.089	.064
1936	409,251	31	.076	.055
1937	415,425	31	.075	.055
1938	319,242	23	.072	.055
1939	359,371	15	.042	.033
1940	418,960	28	.067	.054
1941	460,292	24	.052	.048
1942	516,222	16	.031	.026
1943	513,651	27	.053	.044
1944	519,972	19	.037	.030

TABLE 21. - Fatalities due to electricity underground

Year	Tons mined, 1,000's of tons	Fatal accidents	Fatality rates	
			Per million tons	Per million man-hours
1930	447,684	63	0.141	0.097
1931	363,254	62	.171	.122
1932	290,068	42	.145	.104
1933	315,394	46	.146	.097
1934	338,576	53	.156	.107
1935	348,722	43	.123	.089
1936	409,251	44	.108	.079
1937	415,425	52	.125	.092
1938	319,242	38	.119	.091
1939	359,371	49	.136	.107
1940	418,960	30	.072	.058
1941	460,292	42	.091	.075
1942	516,222	51	.099	.082
1943	513,651	33	.064	.054
1944	519,972	26	.050	.041

Note: Table 21 does not include fatalities in coal mines due to explosions and fires caused by electricity.

Much progress has been made by the manufacturers of electrically driven mining equipment and accessories in attempting to make the equipment safe for use in gassy mines if the equipment is maintained in proper operating condition and is used with care and judgment; accidents caused by electricity have been due largely to the use of open or nonpermissible equipment, but some serious accidents have been caused by permissible equipment that has not been maintained in permissible condition, as a result of which gas has ignited. Improper grounding of equipment has caused shock hazards, some resulting in death. The guarding of overhead electric-trolley wires is more common than formerly, particularly at the places where the man-trips are loaded and unloaded, though numerous deaths are caused by contact with unguarded trolley wires. Trailing-cable insulation is improved and is being improved further at present; electric circuits are being improved and sectionalized; and circuit breakers are being installed to prevent overloading the circuits to a greater extent now than in the past. All of these improvements and many others have helped to reduce the accidents due to electricity, but such accidents continue to occur far too frequently.

The fatality rates from electrical contacts in bituminous-coal and lignite mines on both the million-ton basis and the million-man-hour basis are shown in table 21.

Shaft Accidents

The number of fatal accidents occurring in shafts at underground bituminous-coal and lignite mines has been reduced more than the number of fatal accidents from any of the other principal causes, when considered on a percentage basis. In 1906 73 men lost their lives in shaft accidents, and in 1939 there were only 5 fatal accidents from this cause and only 6 in 1942. The number of fatal shaft accidents in bituminous coal mines that occurred annually in the period 1906 to 1944, inclusive, is shown in table 22.

The reduction in the number of fatal shaft accidents is largely due to improvements in hoisting equipment, safeguards at the collar of the shafts and at shaft landings and in cages and skips, and improved methods of handling cars on and off the mine cages and of handling men in hoisting shafts and slopes.

The danger of falling-cage accidents in hoisting and lowering men is always present, however, and if a cage falls while men are being hoisted or lowered into a mine, a major disaster is likely to result, as cage catches are by no means always dependable. The need for constant and close inspection of hoisting equipment by competent persons is imperative, and it should be remembered that no device that will stop and suspend a falling cage under all conditions of service, and do it every time, has yet been invented.

The fatality rates in shaft accidents in bituminous-coal and lignite mines, based upon millions of tons of coal mined and upon millions of man-hours of exposure, are shown in table 22.

TABLE 22. - Fatalities due to shaft accidents at bituminous-coal and lignite mines

Year	Tons mined, 1,000's of tons	Fatal accidents	Fatality rates	
			Per million tons	Per million man-hours
1930	447,684	9	0.021	0.014
1931	363,254	19	.052	.037
1932	290,068	13	.045	.032
1933	315,394	10	.032	.021
1934	338,576	9	.026	.018
1935	348,722	13	.037	.027
1936	409,251	11	.027	.019
1937	415,425	15	.036	.026
1938	319,242	9	.028	.022
1939	359,371	5	.014	.011
1940	418,960	12	.029	.023
1941	460,292	9	.019	.016
1942	516,222	6	.012	.010
1943	513,651	5	.010	.008
1944	519,972	28	.054	.044

Major Coal-mine Disasters

In relatively recent years, the coal-mining industry has worked more than 12 consecutive months without a major disaster, none having occurred between July 2, 1938 and July 14, 1939. In 1933, only one major disaster occurred, an explosion at Oakmont mine, Barking, Pa., in which seven men lost their lives. In 1946, only two major disasters occurred, causing 27 fatalities. Records of recent years in which relatively few fatalities occurred as a result of major disasters are tabulated below:

Year	Number of major disasters	Fatalities
1933	1	7
1939	1	28
1934	2	22
1946	2	27

The best explosion-free record for the coal-mining industry of the United States was established in the period June 2, 1938 to July 14, 1939, or approximately 13-1/2 months without a major coal mine disaster. On June 2, 1938, an explosion occurred in the Butler slope, Pittston, Pa., (an anthracite mine), and 10 men were killed; the next mine explosion occurred on July 14, 1939, at the Duvin mine, Providence, Ky. (a bituminous mine), with 28 fatalities.

The importance of discussing these relatively short periods in which no major disasters occur when considering the status of safety in mining is that these records indicate that although major disasters are likely to occur in the coal mines of the United States as long as we produce coal in quantities such as now produced, coal mining can be done with major disasters greatly

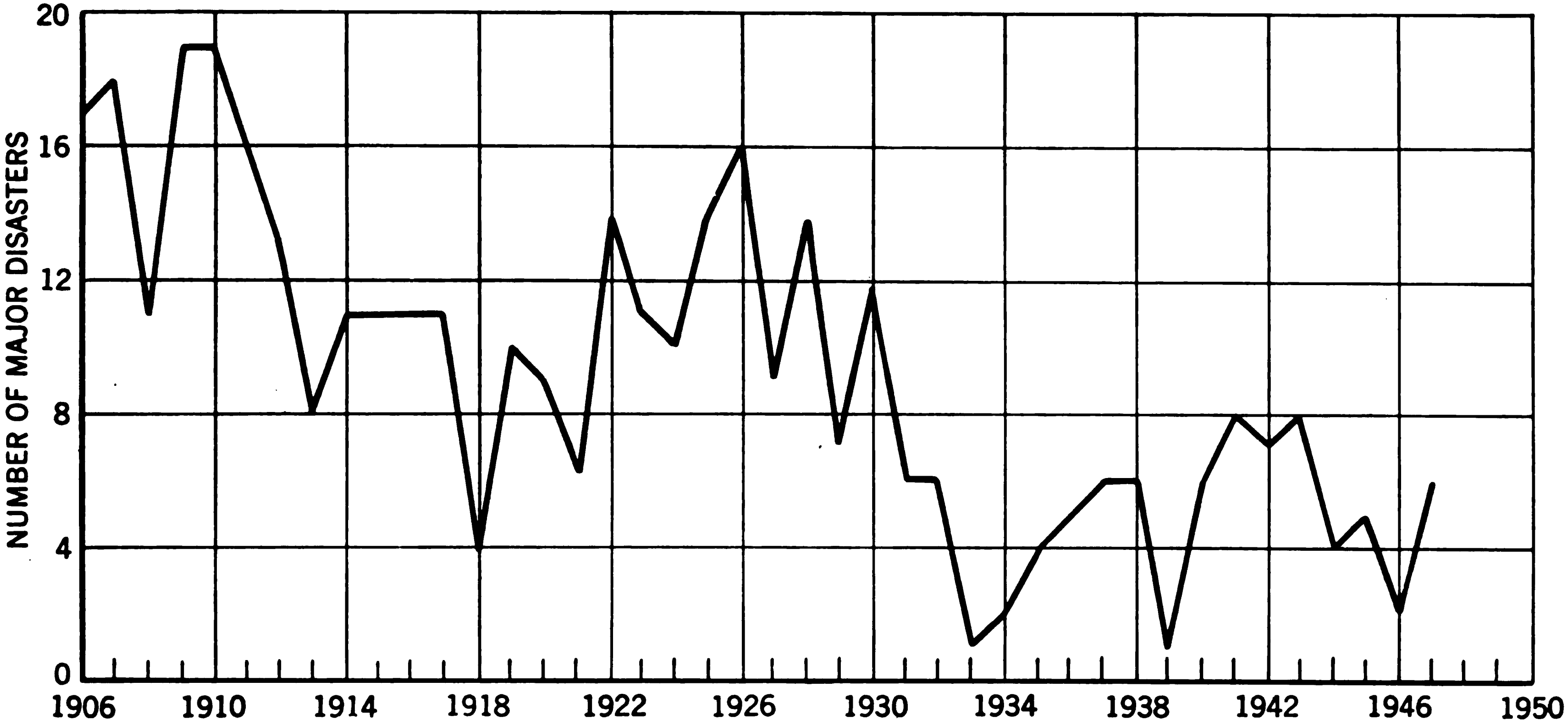

Figure 10. - Number of major coal-mine disasters in the United States, 1906-1947.

in number and in severity, and the terrific toll of life entailed by them can and should be avoided in large part. However, not only individual fatalities but also occasional major disasters are certain to continue to occur in our coal mines, because no amount of laws, regulations, or welfare procedures will ever overcome the vagaries of human beings, and even at present most of the individual accidents as well as major disasters are caused by human failings chargeable to both workers and management, the responsibility being about equally divided.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed

Date	Name of mine	Location of mine	Nature of disaster	Killed
1906:				
Jan. 4	Coaldale	Coaldale, W. Va.	Explosion	22
Jan. 18	Detroit	Detroit, W. Va.	do.	18
Jan. 24	Poteau No. 6	Witteville, Okla.	Dynamite explosion	14
Feb. 8	Parral	Parral, W. Va.	Explosion	23
Feb. 19	Maitland	Walsenburg, Colo.	do.	14
Feb. 27	Little Cahaba	Piper, Ala.	do.	12
Mar. 22	Century No. 1	Century, W. Va.	do.	23
Apr. 22	Cuatro	Tercio, Colo.	do.	18
May 15	Shenandoah City[1]	Shenandoah, Pa.	Dynamite explosion	7
June 7	Red Lodge	Red Lodge, Mont.	Mine fire	8
Aug. 6	Susquehanna No. 7[1]	Nanticoke, Pa.	Explosion	6
Oct. 3	Pocahontas	Pocahontas, Va.	do.	35
Oct. 5	Dutchman	Blossburg, N. Mex.	do.	10
Oct. 24	Rolling Mill	Johnstown, Pa.	do.	7
Nov. 3	San Toy No. 1	Corning, Ohio	Fell down shaft	5
Dec. 20	Fidelity No. 1	Stone City, Kans.	Powder explosion	7
Dec. 22	Breese-Trenton	Breese, Ill.	Cage with men fell down shaft	6
1907:				
Jan. 14	Deering No. 7	Clinton, Ind.	Powder explosion	7
Jan. 23	Primero	Primero, Colo.	Explosion	24
Jan. 26	Lorentz	Penco, W. Va.	Powder explosion	12
Jan. 29	Johnston City	Johnston City, Ill.	do.	7
Jan. 29	Stuart	Stuart, W. Va.	Explosion	84
Feb. 4	Thomas No. 25	Thomas, W. Va.	do.	25
Mar. 2	Holden[1]	Taylor, Pa.	do.	7
Mar. 16	Bond and Bruce	Tacoma, Va.	do.	11
Apr. 26	Morgan	Black Diamond, Wash.	do.	7
May 1	Whipple	Scarboro, W. Va.	do.	16
May 19	Engleville	Engleville, Colo.	Mine fire	5
June 18	Johnson No. 1[1]	Priceburg, Pa.	Explosion	7
Aug. 17	Sonman	Sonman, Pa.	Fell down shaft	5
Dec. 1	Naomi	Fayette City, Pa.	Explosion	34
Dec. 6	Monongah Nos. 6 & 8	Monongah, W. Va.	do.	361
Dec. 16	Yolande	Yolande, Ala.	do.	57
Dec. 19	Darr	Jacobs Creek, Pa.	do.	239
Dec. 31	Bernal	Carthage, N. Mex.	do.	11

See footnote at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1908:				
Jan. 30	Backman	Hawks Nest, W. Va.	Explosion	9
Feb. 10	Moody	South Carrollton, Ky.	do.	9
Mar. 28	Hanna No. 1	Hanna, Wyo.	do.	59
May 12	Mt. Lookout[1]	Wyoming, Pa.	do.	12
May 13	Prospect[1]	Midvale, Pa.	Fall of roof	5
July 15	Williamstown[1]	Williamstown, Pa.	Powder explosion	6
Aug. 26	Hailey-Ola No. 1	Haileyville, Okla.	Mine fire	29
Aug. 28	Warrior Run[1]	Wilkes-Barre, Pa.	Mine cars	6
Nov. 20	Red Lodge	Red Lodge, Mont.	Mine fire	9
Nov. 28	Rachel and Agnes	Marianna, Pa.	Explosion	154
Dec. 29	Lick Branch	Switchback, W. Va.	do.	50
1909:				
Jan. 10	Zeigler	Zeigler, Ill.	Explosion (and mine fire)	26
Jan. 12	Lick Branch	Switchback, W. Va.	Explosion	67
Jan. 19	Stone Canyon	Chancellor, Calif.	do.	6
Jan. 25	Washington No. 5	Franklin, Md.	Mine cars (surface)	5
Jan. 25	Orenda No. 2	Boswell, Pa.	Explosion	5
Feb. 2	Short Creek	Short Creek, Ala.	do.	18
Mar. 2	No. 14[1]	Pittston, Pa.	do.	8
Mar. 20	Sunnyside	Evansville, Ind.	do.	6
Mar. 31	Echo	Buery, W. Va.	Dynamite explosion	6
Apr. 9	Eureka No. 37	Windber, Pa.	do.	7
June 23	Lackawanna No. 4	Wehrum, Pa.	Explosion	21
July 6	Toller	Tollerville, Colo.	do.	9
Oct. 3	Northwestern	Roslyn, Wash.	do.	10
Oct. 21	Rock Island No. 8	Hartshorne, Okla.	do.	10
Oct. 31	Franklin No. 2	Johnstown, Pa.	do.	13
Nov. 9	Auchincloss[1]	Nanticoke, Pa.	Mine fire	9
Nov. 13	St. Paul No. 2	Cherry, Ill.	do.	259
Dec. 11	Baker No. 5	Clay, Ky.	Explosion	7
Dec. 23	Mine A	Herrin, Ill.	do.	8
1910:				
Jan. 11	Nottingham[1]	Plymouth, Pa.	do.	7
Jan. 31	Primero	Primero, Colo.	do.	75
Feb. 1	Browder	Browder, Ky.	do.	34
Feb. 5	Ernest No. 2	Ernest, Pa.	do.	12
Feb. 8	Barthell No. 1	Stearns, Ky.	do.	6
Mar. 12	South Wilkes-Barre No. 5[1]	Wilkes-Barre, Pa.	do.	7
Mar. 31	Great Western No. 2	Wilburton, Okla.	do.	6
Apr. 20	Mulga	Mulga, Ala.	do.	40
Apr. 21	Amsterdam	Amsterdam, Ohio	do.	15
May 5	Palos No. 3	Palos, Ala.	do.	90

See footnote at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1910:				
Oct. 8	Starkville	Starkville, Colo.	Explosion	56
Nov. 3	Yolande No. 1	Yolande, Ala.	do.	5
Nov. 6	Lawson	Black Diamond, Wash.	do.	16
Nov. 8	Victor American No. 3	Delagua, Colo.	Explosion (and mine fire)	79
Nov. 11	Shoal Creek No. 1	Panama, Ill.	Explosion	6
Nov. 25	Providence No. 3	Providence, Ky.	Powder explosion	10
Dec. 14	Greene	Tacoma, Va.	Explosion	8
Dec. 14	Leyden	Leyden, Colo.	Mine fire	10
Dec. 31	Lick Fork	Thacker, W. Va.	Mine cars	10
1911:				
Jan. 20	Carbon Hill	Carbon Hill, Va.	Explosion	7
Feb. 9	Cokedale	Trinidad, Colo.	do.	17
Mar. 18	No. 16	Mineral, Kans.	do.	5
Mar. 22	Hazel	East Canonsburg, Pa.	Fall of roof	9
Apr. 7	Price-Pancoast[1]	Throop, Pa.	Mine fire	72
Apr. 8	Banner	Littleton, Ala.	Explosion	128
Apr. 24	Ott No. 20	Elk Garden, W. Va.	do.	23
May 27	Cameron[1]	Shamokin, Pa.	do.	5
July 13	Sykesville	Skyesville, Pa.	do.	21
Aug. 1	Standard	Welch, W. Va.	do.	6
Sept. 12	Marvine[1]	Scranton, Pa.	Mine cars	5
Oct. 3	Drifton No. 2[1]	Freeland, Pa.	Cave-in	5
Oct. 23	O'Gara No. 9	Harrisburg, Ill.	Explosion	8
Nov. 9	Adrian	Punxsutawney, Pa.	do.	8
Nov. 18	Bottom Creek	Vivian, W. Va.	do.	18
Dec. 9	Cross Mountain	Briceville, Tenn.	do.	84
1912:				
Jan. 9	Parrish[1]	Plymouth, Pa.	do.	6
Jan. 16	Carbon Hill	Carbon Hill, Va.	Dynamite explosion	5
Jan. 19	Central	Central City, Ky.	Explosion	5
Jan. 20	Kemmerer No. 4	Kemmerer, Wyo.	do.	6
Feb. 22	Western No. 5	Lehigh, Okla.	Mine fire	9
Mar. 20	San Bois No. 2	McCurtain, Okla.	Explosion	73
Mar. 26	Jed	Jed, W. Va.	do.	81
Apr. 21	Coil	Madisonville, Ky.	do.	5
June 18	Hastings	Hastings, Colo.	do.	12
July 11	Panama	Moundsville, W. Va.	do.	8
July 16	Old Dominion No. 1	Carbon Hill, Va.	do.	8
July 24	Superba and Lemont	Evans Station, Pa.	Cloudburst flooded mine	[2]18
Aug. 13	Abernant	Abernant, Ala.	Explosion	18
1913:				
Feb. 19	Seagraves	Eldorado, Ill.	do.	5
Apr. 23	Cincinnati	Finleyville, Pa.	do.	96
May 6	Taylor	Hartford, Ky.	Overcome by gas	5

See footnotes at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1913:				
May 17	Imperial	Belle Valley, Ohio	Explosion	15
Aug. 2	East Brookside[1]	Tower City, Pa.	do.	19
Oct. 22	Stag Canon No. 2	Dawson, N. Mex.	do.	263
Nov. 18	Acton No. 2	Acton, Ala.	do.	24
Dec. 16	Vulcan	New Castle, Colo.	do.	37
1914:				
Jan. 10	Rock Castle	Rock Castle, Ala.	do.	12
Jan. 14	Spencer-Newland	Mulberry, Kans.	Cage with men fell down shaft	6
Apr. 28	Eccles Nos. 5 & 6	Eccles, W. Va.	Explosion	181
Apr. 29	Union Pacific No. 2	Cumberland, Wyo.	Mine cars	5
May 29	Maryd[1]	Maryd, Pa.	Overwinding of cage	6
June 30	Cinderella	Cinderella, W. Va.	Suffocated by fumes from fire in fan house	5
Sept. 4	No. 1	Adamson, Okla.	Cave-in	13
Sept. 16	Lehigh No. 4[1]	Lansford, Pa.	Explosion	7
Oct. 5	Mulga	Mulga, Ala.	do.	17
Oct. 27	North or No. 1	Royalton, Ill.	do.	52
Dec. 9	Tripp[1]	Scranton, Pa.	Collapse of bottom of cage	13
1915:				
Feb. 6	Carlisle	Carlisle, W. Va.	Explosion	21
Feb. 17	Prospect[1]	Wilkes-Barre, Pa.	do.	13
Feb. 18	Atlas	Rich Hill, Mo.	Powder (and mine explosion	5
Mar. 2	Layland No. 3	Layland, W. Va.	Explosion	112
Apr. 5	Shoal Creek	Panama, Ill.	do.	11
May 24	Smokeless Valley No. 1	Johnstown, Pa.	do.	9
July 27	United Coal No. 1	Christopher, Ill.	do.	9
July 30	Patterson No. 2	Elizabeth, Pa.	Mine cars	9
Aug. 31	Orenda	Boswell, Pa.	Explosion	19
Nov. 16	Northwestern	Ravensdale, Wash.	do.	31
Nov. 30	Boomer No. 2	Boomer, W. Va.	do.	23
1916:				
Feb. 8	Lance[1]	Plymouth, Pa.	do.	7
Feb. 11	Jefferson and Clearfield No. 2	Ernest, Pa.	do.	27
Feb. 29	Davis No. 42	Kempton, Md.	do.	16
Mar. 9	Hollenback[1]	Wilkes-Barre, Pa.	do.	6
Mar. 28	King	Kimball, W. Va.	do.	6
Mar. 30	Robindale	Seward, Pa.	do.	8
Aug. 8	Woodward[1]	Edwardsville, Pa.	do.	6

See footnote at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1916:				
Oct. 19	Jamison No. 7	Barrackville, W. Va.	Explosion	10
Oct. 22	Roden	Marvel, Ala.	do.	18
Nov. 4	Bessie	Palos, Ala.	do.	30
Dec. 13	Fidelity No. 9	Stone City, Kans.	do.	20
1917:				
Mar. 13	Henderson No. 1	Hendersonville, Pa.	do.	14
Apr. 18	Lynden	Mason, W. Va.	Lightning exploded powder in powder house	5
Apr. 27	Hastings	Hastings, Colo.	Explosion	121
June 2	Rend No. 2	Herrin, Ill.	do.	9
June 13	Banner	Banner, Ala.	do.	6
Aug. 4	West Ky. No. 7	Clay, Ky.	do.	62
Nov. 29	Old Ben. No. 11	Christopher, Ill.	do.	17
Dec. 15	Yukon No. 1	Bluefield, W. Va.	do.	17
Dec. 17	Wilkeson	Wilkeson, Wash.	Inrush of water and gravel	6
Dec. 19	No. 3	Nemo, Tenn.	Explosion	11
Dec. 31	Underwood[1]	Throop, Pa.	do.	20
1918:				
May 20	Villa	Charleston, W. Va.	Mine fire	13
Aug. 7	Harmar	Harmarville, Pa.	Explosion	8
Aug. 28	Burnett	Burnett, Wash.	do.	12
Sept. 28	North	Royalton, Ill.	do.	21
1919:				
Mar. 31	Empire	Aguilar, Colo.	do.	13
Apr. 29	Majestic	Majestic, Ala.	do.	22
June 5	Baltimore tunnel No. 2[1]	Wilkes-Barre, Pa.	Powder explosion	92
June 30	Alderson No. 5	Alderson, Okla.	Explosion	15
July 8	Lansford colliery[1]	Lansford, Pa.	do.	8
July 18	Carswell	Kimball, W. Va.	do.	6
Aug. 6	Weirwood	Weirwood, W. Va.	do.	7
Aug. 18	Oakdale	Laveta, Colo.	do.	18
Oct. 29	Amsterdam No. 2	Amsterdam, Ohio	Mine fire	20
Dec. 4	No. 3	Jasonville, Ind.	Explosion	6
1920:				
Apr. 14	Stag Canon Nos. 1 & 6	Dawson, N. Mex.	do.	5
May 3	Submarine	Clinton, Ind.	do.	5
June 2	Ontario	Cokesburg, Pa.	do.	6
July 19	Union	Renton, Pa.	do.	9
July 26	No. 6	Sublet, Wyo.	Blowing up of powder magazine	8
Aug. 13	Pounding Mill	Pounding Mill, Va.	Fall of rock	9

See footnote at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1920:				
Aug. 21	No. 19	Degnan, Okla.	Explosion	10
Nov. 16	Arnold	Earlington, Ky.	Mine fire	6
Nov. 23	Parrish	Parrish, Ala.	Explosion	12
1921:				
Feb. 12	Oak Hill Nos. 1 & 2	Oak Creek, Colo.	do.	5
Feb. 23	Kathleen	Dowell, Ill.	Mine fire	7
Mar. 9	Rahn No. 11[1]	Seek, Pa.	Explosion	5
Aug. 31	Harco	Harrisburg, Ill.	do.	11
Dec. 13	Satanic	Morrison, Colo.	Mine fire	6
Dec. 31	Docena	Adamsville, Ala.	Explosion	5
1922:				
Jan. 30	Layman	Pineville, Ky.	do.	6
Feb. 2	Belle Ellen No. 2	Belle Ellen, Ala.	do.	9
Feb. 2	Gates No. 2	Brownsville, Pa.	do.	25
Feb. 7	Marietta	Pinson Fork, Ky.	do.	9
Mar. 20	Dilltown No. 1	Dilltown, Pa.	do.	5
Mar. 24	Sopris	Sopris, Colo.	do.	17
May 25	Acmar No. 3	Acmar, Ala.	do.	11
Sept. 23	Raleigh-Wyoming No. 2	Glen Rogers, W. Va.	Falling cage	5
Sept. 29	Lake Creek	Johnston City, Ill.	Explosion	5
Oct. 30	No. 11	McCurtain, Okla.	do.	8
Nov. 3	Eddy Creek[1]	Olyphant, Pa.	Premature shot	6
Nov. 6	Reilly No. 1	Spangler, Pa.	Explosion	77
Nov. 22	Dolomite No. 3	Dolomite, Ala.	do.	90
Nov. 25	No. 4	Cerillos, N. Mex.	do.	12
1923:				
Jan. 10	Dolomite No. 1	Dolomite, Ala.	do.	5
Feb. 8	Stag Canon No. 1	Dawson, N. Mex.	do.	120
Feb. 21	Alliance[1]	Kaska, Pa.	do.	5
Mar. 2	Arista	Arista, W. Va.	do.	10
May 5	Southwestern	Aguilar, Colo.	do.	10
June 26	Richards colliery[1]	Mount Carmel, Pa.	do.	5
Aug. 14	Frontier No. 1	Kemmerer, Wyo.	do.	99
Oct. 7	Midwest	Palisades, Colo.	do.	6
Nov. 6	Glen Rogers	Beckley, W. Va.	do.	27
Dec. 7	Happy	Happy, Perry Co., Ky.	do.	9
Dec. 8	Mt. Jessup No. 2[1]	Jessup, Pa.	Fall of roof	5
1924:				
Jan. 24	McClintock	Johnston City, Ill.	Explosion	33
Jan. 26	Lancashire No. 18	Shanktown, Pa.	do.	36
Mar. 8	No. 2	Castle Gate, Utah	do.	171
Mar. 28	Yukon No. 2	Yukon, W. Va.	do.	24
Apr. 28	Benwood	Benwood, W. Va.	do.	119

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[1] See footnote at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1924:				
June 6	Locmis[1]	Wilkes-Barre, Pa.	Explosion	14
July 25	Gates No. 1	Brownsville, Pa.	do.	10
Sept. 16	Sublet No. 5	Sublet, Wyo.	do.	39
Sept. 21	Rains	Rains, Utah	do.	5
Dec. 17	Burnett	Burnett, Wash.	do.	7
1925:				
Jan. 15	Diamond No. 1	Providence, Ky.	do.	6
Feb. 20	City	Sullivan, Ind.	do.	52
Mar. 17	Barrackville	Barrackville, W. Va.	do.	33
Apr. 26	Hutchison	West Newton, Pa.	do.	5
May 26	Woodward[1]	Edwardsville, Pa.	do.	7
May 27	Farmville	Coal Glen, N. C.	do.	53
May 31	No. 2	Piper, Ala.	do.	7
June 8	No. 9	Sturgis, Ky.	do.	17
July 23	Rockwood	Rockwood, Tenn.	do.	10
Aug. 3	Dorrance[1]	Wilkes-Barre, Pa.	do.	10
Nov. 13	Finley	Madisonville, Ky.	do.	5
Dec. 10	Overton No. 2	Acmar, Ala.	do.	53
Dec. 14	Wilkeson	Tacoma, Wash.	do.	5
Dec. 23	Webb	Bellaire, Ohio	Mine fire	9
1926:				
Jan. 13	No. 21	Wilburton, Okla.	Explosion	91
Jan. 14	Jamison No. 8	Farmington, W. Va.	do.	19
Jan. 29	New Orient No. 2	West Frankfort, Ill.	do.	5
Jan. 29	Mossboro No. 1	Helena, Ala.	do.	27
Feb. 3	Horning No. 4	Horning, Pa.	do.	20
Feb. 16	Nelson	Nelson Creek, Ky.	do.	8
Mar. 8	Crab Orchard No. 5	Eccles, W. Va.	do.	19
May 6	Randolph colliery[1]	Port Carbon, Pa.	do.	5
July 3	Pettebone[1]	Kingston, Pa.	do.	7
July 21	Dixie	Moffat, Ala.	do.	9
Aug. 26	Clymer No. 1	Clymer, Pa.	do.	44
Sept. 3	Tahona	Tahona, Okla.	do.	16
Oct. 4	Rockwood	Rockwood, Tenn.	do.	27
Oct. 30	Colliery No. 7[1]	Nanticoke, Pa.	do.	9
Nov. 15	Mound	Moundsville, W. Va.	do.	5
Dec. 9	Francisco No. 2	Francisco, Ind.	do.	37
1927:				
Mar. 30	Saline No. 2	Ledford, Ill.	do.	8
Apr. 2	No. 53	Cokeburg, Pa.	do.	6
Apr. 8	Carbonado	Carbonado, Wash.	Rush of gravel and mud	7
Apr. 30	Federal No. 3	Everettville, W. Va.	Explosion	97
May 13	Shanon Branch No. 3	Capels, W. Va.	do.	8
May 26	Woodward[1]	Edwardsville, Pa.	do.	7
May 27	Delagua	Delagua, Colo.	do.	7

See footnote at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1927:				
Aug. 3	Clay No. 7	Clay, Ky.	Explosion	15
Dec. 20	Franco No. 1	Johnston City, Ill.	do.	7
1928:				
Jan. 9	No. 18	West Frankfort, Ill.	do.	21
Feb. 20	Kinloch	Parnassus, Pa.	do.	12
Feb. 24	Mama No. 3	Jenny Lind, Ark.	do.	13
Apr. 2	Keystone No. 2	Keystone, W. Va.	do.	8
May 19	Mather No. 1	Mather, Pa.	do.	195
May 22	No. 30	Harlan, Ky.	do.	8
May 22	No. 1	Yukon, W. Va.	do.	17
May 25	Baltimore No. 5[1]	Parsons, Pa.	do.	10
June 20	No. 1	National, W. Va.	do.	6
Aug. 9	Hillside	Johnstown, Pa.	do.	5
Aug. 15	No. 3	Coalport, Pa.	do.	13
Oct. 22	McAlpin	McAlpin, W. Va.	do.	6
Nov. 30	Pricess Poca	Roderfield, W. Va.	do.	6
Dec. 19	No. 2	Drakesboro, Ky.	do.	6
1929:				
Jan. 26	Kingston No. 5	Kingston, W. Va.	do.	[2]14
Mar. 21	Kinloch	Parnassus, Pa.	do.	46
Mar. 27	Connellsville	Yolande, Ala.	do.	10
June 5	Halcon	Bear Crrek, Va.	Fall of slate	5
Sept. 27	Covington	Tahona, Okla.	Explosion	8
Dec. 1	Old Ben No. 8	West Frankfort, Ill.	do.	7
Dec. 17	Old Town	McAlester, Okla.	do.	61
1930:				
Jan. 13	Peerless	Straven, Ala.	do.	7
Jan. 19	No. 1	Lillybrook, W. Va.	do.	8
Feb. 6	Standard	Standardville, Utah	do.	[2]23
Mar. 8	New Peerless	Lynn, Utah	do.	5
Mar. 26	Yukon	Arnettsville, W. Va.	do.	12
Mar. 30	Kettle Island	Kettle Island, Ky.	do.	16
Apr. 12	Carbonado	Carbonado, Wash.	do.	17
Aug. 8	Gilberton colliery[1]	Gilberton, Pa.	Fall of roof	8
Oct. 27	Wheatley No. 4	McAlester, Okla.	Explosion	30
Nov. 5	No. 6	Millfield, Ohio	do.	[3]79
Nov. 29	Lutie No. 5	Wilburton, Okla.	do.	15
Dec. 6	Lamb	Madried, N. Mex.	do.	5
1931:				
Jan. 3	Midvale No. 4	Midvale, Ohio	do.	5
Jan. 6	No. 2	Beckley, W. Va.	do.	8
Jan. 28	Little Betty	Dugger, Ind.	do.	28
May 29	Richards colliery[1]	Mount Carmel, Pa.	do.	5
Nov. 3	No. 20	Holden, W. Va.	do.	5
Dec. 28	Overton No. 1	Irondale, Ala.	do.	5

See footnotes at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1932:				
Jan. 18	Parrott	Parrott, Va.	Explosion	6
Feb. 27	Boissevain	Boissevain, Va.	do.	38
June 13	Splashdam No. 6	Splashdam, Va.	do.	10
Dec. 7	Jones	Madrid, N. Mex.	do.	14
Dec. 9	Zero	Yancey, Ky.	do.	23
Dec. 23	Shafer	Moweaqua, Ill.	do.	54
1933:				
Sept. 11	Oakmont	Barking, Pa.	do.	7
1934:				
Mar. 12	No. 10	Wheatcroft, Ky.	Asphyxiation	5
Aug. 6	Derby No. 3	Big Stone Gap, Va.	Explosion	17
1935:				
Jan. 21	Gilberton[1]	Gilberton, Pa.	do.	13
May 7	South Wilkes-Barre[1]	Wilkes-Barre, Pa.	Rock fell down shaft and struck ascending cage	7
May 11	Barrackville	Barrackville, W. Va.	Fire in hoisting shaft	6
July 17	No. 5	Van Lear, Ky.	Explosion	9
1936:				
Jan. 30	Monarch No. 2	Broomfield, Colo.	do.	8
Aug. 1	Kathleen	Dowell, Ill.	Mine fire	9
Aug. 24	Clear Spring[1]	West Pittston, Pa.	Explosion	5
Sept. 2	Macbeth	Logan, W. Va.	do.	10
Nov. 19	No. 1	Bates, Ark.	do.	5
1937:				
Mar. 11	Macbeth	Logan, W. Va.	do.	18
Mar. 28	Kramer	DuBois, Pa.	do.	9
June 21	Rupert (Keystone)	Keystone, Ohio	Powder explosion	6
July 15	Baker	Sullivan, Ind.	Explosion	20
Oct. 15	Mulga	Birmingham, Ala.	do.	34
Oct. 26	Jonesville	Jonesville, Alaska	do.	14
1938:				
Jan. 12	Harwick	Harwick, Pa.	do.	10
Feb. 11	Vail (Star Valley)	Afton, Wyo.	do.	5
Apr. 22	Keen Mountain	Grundy, Va.	do.	45
Apr. 27	No. 1 Slope[1]	Pottsville, Pa.	do.	8
June 2	Butler Slope[1]	Pittston, Pa.	do.	10
July 1	Praco No. 7	Praco, Ala.	Fall of rock	6
1939:				
July 14	Duvin	Providence, Ky.	Explosion	28
1940:				
Jan. 10	No. 1	Bartley, W. Va.	do.	91
Mar. 16	Willow Grove No. 10	St. Clairsville, Ohio	do.	72
July 15	Sonman	Portage, Pa.	do.	63
Aug. 27	No. 2	Bates, Ark.	do.	10

See footnote at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Date	Name of mine	Location of mine	Nature of disaster	Killed
1940:				
Nov. 29	Nelms	Cadiz, Ohio	Explosion	31
Dec. 17	No. 4	Beckley, W. Va.	do.	9
1941:				
Jan. 22	Carswell	Kimball, W. Va.	do.	6
Feb. 14	No. 11 (strip)	Du Quoin, Ill.	Explosives	7
May 22	Panhandle No. 2	Bicknell, Ind.	Explosion	14
June 4	Docena	Adamsville, Ala.	do.	5
June 30	Kent	McIntyre, Pa.	do.	7
July 10	Acmar No. 6	Acmar, Ala.	do.	11
Oct. 27	Daniel Boone	St. Charles, Ky.	do.	15
Dec. 28	No. 47	Harco, Ill.	do.	8
1942:				
Jan. 27	Wadge	Mt. Harris, Colo.	do.	34
May 11	Peerless	Greenwood, Ark.	do.	6
May 12	Christopher No. 3	Osage, W. Va.	do.	56
May 18	Hitchman	Benwood, W. Va.	do.	5
July 9	No. 2	Pursglove, W. Va.	do.	20
Nov. 30	No. 10	Providence, Ky.	do.	6
Dec. 15	Laing No. 1	Laing, W. Va.	Surface haulage	5
1943:				
Jan. 8	No. 15	Pursglove, W. Va.	Mine fire	17
Feb. 27	Smith	Red Lodge, Mont.	Explosion	75
May 5	NuRex	Lafollette, Tenn.	do.	10
May 11	Praco No. 10	Praco, Ala.	do.	12
Aug. 28	Sayreton No. 2	Sayreton, Ala.	do.	28
Sept. 16	3 Point	Harlan, Ky.	do.	12
Sept. 24	M & S[1]	Minersville, Pa.	do.	14
Nov. 6	Nellis	Madison, W. Va.	do.	11
1944:				
Mar. 25	Katherine No. 4	Shinnston, W. Va.	do.	16
June 8	Emerald	Clarksville, Pa.	Mine fire	6
July 5	Powhatan	Belmont, Ohio	Trapped by fire	66
July 28	Brilliant	Brilliant, N. Mex.	Explosion	6
1945:				
Jan. 17	Craig No. 2	Pittsburg, Okla.	do.	9
Mar. 12	Crucible	Greene, Pa.	Fall of roof	5
Mar. 14	Kennilworth	Carbon, Utah	Explosion	7
May 9	No. 1	Sunnyside, Utah	do.	23
Dec. 26	Belva No. 1	Pineville, Ky.	do.	24
1946:				
Jan. 15	Havaco No. 9	Welch, W. Va.	do.	15
Apr. 18	Great Valley	McCoy, Va.	do.	12
1947:				
Jan. 15	Nottingham[1]	Plymouth, Pa.	do.	15

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[1] See footnote at end of table.

TABLE 23. - Coal-mine disasters in the United States in which five or more men were killed (Cont'd.)

Name	Name of mine	Location of mine	Nature of disaster	Killed
1947:				
Mar. 25	No. 5 mine	Centralia, Ill.	Explosion	111
Apr. 10	Schooley[1]	Wyoming, Pa.	do.	10
Apr. 30	Spring Hill	Terre Haute, Ind.	do.	8
July 24	Old Ben No. 8	West Frankfort, Ill.	do.	27
Dec. 11	Franklin colliery[1]	Wilkes-Barre, Pa.	do.	8

[1] Anthracite mine.
[2] Includes three killed by fall of slate about 28 hours later.
[3] Does not include three visitors in no way connected with mining.

In considering the foregoing, including the admittedly bad disaster record of 1947, it is well to remember that although coal-mine disasters continue to occur, they occur far less frequently and with much smaller loss of life than in the past. Table 24 shows that in the 5 years 1906 to 1910, inclusive, there were 84 major disasters in the coal mines of the United States, or about 17 per year. This is a far cry from the record of 1933, with one major coal-mine disaster, or 1934 with 2, or 1939 with 1, or 1946 with 2; and during the 12-1/2-month period July 1, 1938 to July 14, 1939, there was not a single major disaster in any coal mine in the United States.

TABLE 24. - Major disasters in bituminous and anthracite coal mines of the United States, 1906 to December 31, 1947, inclusive

Year	Major disasters	Fatalities	Fatalities per major disaster	Maximum fatalities in any 1 major disaster
1906	17	235	13.8	35
1907	18	919	51.0	361
1908	11	348	31.6	154
1909	19	498	26.2	259
1910	19	492	25.9	83
	84	2,492	29.7	
1911	16	421	26.3	128
1912	13	254	19.5	81
1913	8	464	58.0	263
1914	11	317	28.7	181
1915	11	262	23.8	112
	59	1,718	29.1	
1916	11	154	14.0	30
1917	11	288	26.2	121
1918	4	54	13.5	21
1919	10	207	20.7	92
1920	9	70	7.7	12
	45	773	17.2	

TABLE 24. - Major disasters in bituminous and anthracite coal mines of the United States, 1906 to December 31, 1947, inclusive (Cont'd.)

Year	Major disasters	Fatalities	Fatalities per major disaster	Maximum fatalities in any 1 major disaster
1921	6	39	6.5	11
1922	14	285	20.3	90
1923	11	301	27.4	120
1924	10	458	45.8	171
1925	14	272	19.3	53
	55	1,355	24.6	
1926	16	348	21.7	91
1927	9	162	18.0	97
1928	14	326	23.3	195
1929	7	151	21.6	61
1930	12	225	18.7	79
	58	1,212	20.9	
1931	6	56	9.3	28
1932	6	145	24.1	54
1933	1	7	7.0	7
1934	2	22	11.0	17
1935	4	35	8.7	13
	19	265	13.9	
1936	5	37	7.4	10
1937	6	101	16.8	34
1938	6	84	14.0	45
1939	1	28	28.0	28
1940	6	276	46.0	91
	24	526	21.9	
1941	8	73	9.1	15
1942	7	132	18.8	56
1943	8	175	20.6	75
1944	4	94	23.5	66
1945	5	68	13.6	24
	32	546	17.1	
1946	2	27	13.5	15
1947	6	179	34.2	111

In the 5-year period 1906 to 1910, inclusive, there were 2,492 fatalities from major coal-mine disasters, or an average of 498 per year; again, this is far different from the 7 fatalities from major disasters in 1933, 22 in 1934, 28 in 1939, 27 in 1946, and the fact that not one person was killed in a major disaster in any coal mine in the United States in the approximate 13-1/2 months June 2, 1938 to July 14, 1939.

It is probable that in 1933, 1934, 1939, and 1946 the coal mines of the United States achieved virtually the irreducible minimum insofar as the occurrence of major coal-mine disasters is concerned, because it is a certainty that as long as heavily producing underground coal mines are operated, major coal mine disasters will occur from time to time.

Major disasters in coal mines are not limited to gas and coal-dust explosions, although explosions predominate over all other causes. Table 25 shows that causes of major disasters include explosives, falling cages and other hoisting accidents, mine fires, haulage, and other causes of mine accidents, and it is evident that precautions should be kept in effect against all of them. Table 25 lists the causes of major disasters by years since 1906; it is of interest to note the distribution of these occurrences over the past four decades.

TABLE 25. - Number of men killed in major disasters, by years and principal causes of the disasters, 1910-1946

Year	Explosions, gas or dust	Explosions of explosives	Cage disasters	Mine fires	Haulage	Falls of roof or cave-ins	Miscellaneous	Total killed
1910	462	10	-	10	10	-	-	492
1911	330	-	-	72	5	14	-	421
1912	222	5	-	9	-	-	18	254
1913	459	-	-	-	-	-	5	464
1914	269	-	25	-	5	13	5	317
1915	248	5	-	-	9	-	-	262
1916	154	-	-	-	-	-	-	154
1917	277	5	-	-	-	-	6	288
1918	41	-	-	13	-	-	-	54
1919	95	92	-	20	-	-	-	207
1920	47	8	-	6	-	9	-	70
1921	26	-	-	13	-	-	-	39
1922	274	6	5	-	-	-	-	285
1923	296	-	-	-	-	5	-	301
1924	458	-	-	-	-	-	-	458
1925	263	-	-	9	-	-	-	272
1926	348	-	-	-	-	-	-	348
1927	155	-	-	-	-	-	7	162
1928	326	-	-	-	-	-	-	326
1929	146	-	-	-	-	5	-	151
1930	217	-	-	-	-	8	-	225
1931	56	-	-	-	-	-	-	56
1932	145	-	-	-	-	-	-	145
1933	7	-	-	-	-	-	-	7
1934	17	-	-	-	-	-	5	22
1935	22	-	-	6	-	-	7	35
1936	28	-	-	9	-	-	-	37
1937	95	6	-	-	-	-	-	101
1938	78	-	-	-	-	6	-	84
1939	28	-	-	-	-	-	-	28

TABLE 25. - Number of men killed in major disasters, by years and principal causes of the disasters, 1910-46 (Cont'd.)

Year	Explosions, gas or dust	Explosions of explosives	Cage disasters	Mine fires	Haulage	Falls of roof or cave-ins	Miscellaneous	Total killed
1940	276	-	-	-	-	-	-	276
1941	66	7	-	-	-	-	-	73
1942	127	-	-	-	5	-	-	132
1943	162	-	-	17	-	-	-	179
1944	22	-	-	72	-	-	-	94
1945	63	-	-	-	-	5	-	68
1946	27	-	-	-	-	-	-	27
1947	179	-	-	-	-	-	-	179
Total	[1]6,511	[1]144	30	256	34	65	53	7,093

[1] Many of those killed in major disasters from "explosions of gas or dust" might be attributed to explosives, because scores of explosions of gas or dust were started by explosives.

Cause of major disasters, 1906 to November 1, 1947	Number of major disasters	Percent of total
Gas and coal-dust explosions	313	81.9
Mine fires	20	5.3
Explosives	18	4.7
Falls of roof and cave-ins	10	2.6
Cage disasters	8	2.1
Haulage	7	1.8
Other causes	6	1.6
	382	100.0

Since 1922, a period of approximately 25 years, the causes of major disasters in coal mines have varied considerably. Gas and coal-dust explosions account for 90 percent of major coal-mine disasters; and mine fires, although still second in frequency, have declined to 3.2 percent of the total; this is shown in the following tabulation:

Cause of major disasters, 1922-1947	Number of disasters	Percent of total
Gas and coal-dust explosions	171	90.0
Mine fires	6	3.2
Falls of roof	5	2.7
Explosives	3	1.6
Cage disasters	2	1.0
Other causes	2	1.0
Haulage	1	.5
	190	100.0

Considering the past 10-year period, 1938 to 1947, the incidence of major disasters, by causes, again changes materially, as shown in the following table:

Cause of major disasters 1938-1947	Number of disasters	Percent of total
Gas and coal-dust explosions	46	86.7
Mine fires	3	5.7
Falls of roof	2	3.8
Explosives	1	1.9
Haulage	1	1.9
Cage disasters	0	-
Other causes	0	-
	53	100.0

However, considering only the past 5-year period, from 1943 to 1947, major disasters in coal mines were due to only three causes, namely:

Cause of major disasters, 1943-1947	Number of disasters	Percent of total
Gas and coal-dust explosions	21	84.0
Mine fires	3	12.0
Falls of roof	1	4.0
Explosives	0	-
Cage disasters	0	-
Haulage	0	-
Other causes	0	-
	25	100.0

It is evident through the entire period since 1906 that gas and dust explosions constituted the predominant cause of major coal mine disasters notwithstanding the fact that it is well known that rock dust, when properly applied and maintained, and adequate ventilation of the working sections of the mine are efficient methods of virtually eliminating widespread explosions from gas and coal dust.

The number of workers killed annually in major coal-mine disasters is shown in table 24; table 25 shows the number of workers killed annually, classified into the principal causes of the disasters for the period 1910 to November 1, 1947. A total of 7,093 fatalities occurred in this period, and of these 6,511, Or 91.7 percent, were killed in major disasters caused by gas or coal-dust explosions. Table 26 shows the number of fatalities caused by major explosions and all other causes.

The second largest cause of loss of life in major disasters was mine fires, with a total of 256 fatalities. The mine fire at the No. 15 mine, Pursglove, W. Va., on January 8, 1943, caused 17 fatalities; the fire at the Powhatan mine, Belmont, Ohio, on July 5, 1944, caused the death of 66 men; and a fire at the Emerald mine, Clarksville, Pa., on June 8, 1944, caused 6 fatalities. Previous to the Pursglove fire in January 1943, there had been no major coal-mine-fire disaster since August 1, 1936, when 9 men were killed in a fire in the Kathleen mine, Dowell, Ill.

TABLE 26. - Fatalities due to major explosions and all other causes at underground bituminous-coal mines in the United States, 1931-47, inclusive

Year	Number of underground fatalities caused by -			Underground fatality rate per million tons, by causes			Percentage of underground fatalities caused by major explosions
	Major explosions	All other causes	Total	Major explosions	All other causes	Total	
1931	51	975	1,026	0.14	2.68	2.82	5.0
1932	145	750	895	.50	2.59	3.09	16.2
1933	7	766	773	.02	2.43	2.45	.9
1934	17	877	894	.05	2.59	2.64	1.9
1935	9	896	905	.03	2.57	2.60	1.0
1936	23	1,011	1,034	.06	2.47	2.53	2.2
1937	95	1,033	1,128	.23	2.49	2.72	8.4
1938	60	763	823	.19	2.39	2.58	7.3
1939	28	795	823	.08	2.21	2.29	3.4
1940	276	860	1,136	.66	2.05	2.71	24.3
1941	66	828	994	.14	2.02	2.16	6.6
1942	127	1,016	1,143	.25	1.96	2.21	11.1
1943	148	982	1,130	.29	1.90	2.19	13.1
1944	22	993	1,015	.04	1.92	1.96	2.2
1945[1]	63	791	854	.14	1.79	1.83	7.4
1946[1]	27	707	734	.06	1.67	1.73	3.7
1947[1]	146	762	908	[2]	[2]	[2]	15.0

[1] Tentative.
[2] Not available.

Other fires in which a large number of coal-mine workers lost their lives were the St. Paul No. 2 mine, Cherry, Ill., in 1909, when 259 men were killed, and the Price-Pancoast mine, Throop, Pa., in 1911, which was responsible for 72 fatalities. The three major disasters from fires in coal mines in 1943 and 1944 were caused by the trolley haulage system; numerous other fires in coal mines have been caused by the trolley system in the past 5 years and for the past 30 or more years the trolley locomotive system has caused several hundred fatalities in coal mines due to fires and explosions initiated in one manner or another by the trolley haulage system.

The number of fatalities resulting from major disasters should be used with considerable care when determining the progress made in coal-mine safety. In some years, fatalities resulting from major disasters constitute a fairly large percentage of the total number of persons killed in coal mines, but the number of persons killed in a disaster depends largely upon the circumstances surrounding the particular disaster. A mine explosion may kill 10 men or 100 men, as the case may be, yet each such explosion is rated as a major disaster.

Eight major disasters occurred in 1913, 1941, and 1943, but the number of fatalities ranged from 464 in 1913 to 73 in 1941 and 179 in 1943. In some respects progress in mine safety, insofar as major disasters are concerned, should take into consideration the number of disasters rather than the number of persons killed, as the frequency of occurrence of these disasters is important in trying to measure progress in major-disaster prevention. However, the severity or, in other words, the number of persons killed is definitely important, and a good gage of progress in mine safety requires that both the number of major disasters per year and the number of fatalities from them be considered. Fortunately for those interested in the matter of preventing (or at least greatly reducing) the havoc created by coal-mine disasters, the record indicates a great reduction in the number of disasters from 84 in the 5-year period 1906 to 1910, inclusive, to 32 in the 5-year period 1941 to 1945, inclusive, and a reduction in fatalities from major coal-mine disasters from 2,492 in the 5-year period 1906 to 1910, inclusive, to 546 in the 5-year period 1941 to 1945, inclusive. This shows a reduction of 62 percent in the number of major disasters and a reduction of 78 percent in the fatalities due to major disasters in comparing the two 5-year periods. Unquestionably, much progress has been made from both points of view, namely, the number of major disasters per 5 years (or per year) and the number killed in major disasters per year or per 5-year period.

Underground Mines and Surface Plants

Underground bituminous-coal and lignite mines and the surface plants at these mines constitute the major part of the industry; statistics for the industry include the tonnage produced at both underground mines and stripping operations; hence, they do not represent the true status of the underground mines only.

Table 27 gives the tonnage of coal produced from underground mines, the fatal and nonfatal accidents that occurred in the underground mines and at the surface plants of those mines, and the rates per million tons of coal for fatal and nonfatal injuries for the period 1930-1944, inclusive. Complete statistics for the years 1945, 1946, and 1947 are not available.

Table 28 gives the millions of man-hours of exposure in underground mines and surface plants at these mines and the total man-hours, the fatal and nonfatal injuries, and the rates for each per million man-hours.

The large increase in the number of man-hours of exposure at the surface plants is noteworthy in the period 1940-1944. The increase is due largely to the lengthened working time during the war as well as to greater number of cleaning plants at the mines.

The fatal and nonfatal injury rates per million tons and per million man-hours of exposure closely follow the injury rates for the entire bituminous coal industry, as would be expected, as most of the bituminous coal and lignite is mined in underground mines. The effect of the lower injury rates of the strippings is clearly shown when the rates for underground mines is compared with the rates for the entire industry. The need for greater effort in reducing mining hazards in underground mines is evident, even though definite but slow progress over the years is shown.

TABLE 27. - Accident rates per million tons of coal produced at underground bituminous-coal and lignite mines and surface plants

Year	Tons of coal produced at underground mines in 1,000's of tons	Injuries		Rates per million tons	
		Fatal	Nonfatal	Fatal	Nonfatal
1930	447,684	1,609	70,345	3.594	157.131
1931	363,254	1,078	53,381	2.968	146.952
1932	290,068	947	38,588	3.265	133.031
1933	315,394	824	43,090	2.613	136.623
1934	338,576	950	46,257	2.806	136.622
1935	348,722	954	46,794	2.736	134.187
1936	409,251	1,083	49,306	2.646	120.479
1937	415,425	1,190	51,572	2.865	124,143
1938	319,242	862	35,758	2.700	112.009
1939	359,371	858	37,411	2.388	104.101
1940	418,960	1,182	42,655	2.821	101.812
1941	460,292	1,038	45,187	2.255	98.170
1942	516,222	1,214	51,733	2.352	100.215
1943	513,651	1,192	49,536	2.321	96.439
1944	519,972	1,074	49,209	2.065	94.638
1945	1/467,630	2/	2/	2/	2/
1946	1/423,000	2/	2/	2/	2/

1/ Estimated by the Coal Economics Division, Bureau of Mines.
2/ Not available.

TABLE 28. - Accident rates per million man-hours of exposure at bituminous-coal and lignite mines and the surface plants at underground mines1/

Year	Thousands of man-hours			Injuries		Rates per million man-hours	
	Underground	Surface	Total	Fatal	Nonfatal	Fatal	Nonfatal
1930	647,986	91,925	739,911	1,609	70,345	2.175	95.072
1931	510,366	76,512	586,878	1,078	53,381	1.837	90.958
1932	404,182	66,413	480,595	947	38,586	2.012	81.998
1933	474,127	81,012	555,139	824	43,090	1.484	77.620
1934	496,437	85,275	581,712	950	46,257	1.633	79.519
1935	485,341	81,726	567,067	954	46,794	1.682	82.519
1936	559,734	95,033	654,767	1,083	49,306	1.654	75.303
1937	565,071	92,970	658,041	1,190	51,572	1,808	78.372
1938	417,345	71,662	489,007	862	35,768	1.763	73.124
1939	457,965	78.337	536,302	858	37,411	1.600	69,757
1940	516,346	87,500	603,846	1,182	42,655	1.957	70.639
1941	563,236	98,101	661,337	1,038	45,187	1.570	68.327
1942	621.472	116,369	737,841	1,214	51,733	1.645	70.114
1943	610,834	126,429	737,263	1,192	49,536	1.617	67.189
1944	638,349	140,318	778,667	1,074	49,209	1.379	63.196

1/ Statistics for 1945 and 1946 are not yet available.

Strip Coal Mining

Coal mining by open-cut methods, commonly called strip coal, has increased tremendously within the last few years. Larger and improved excavating equipment and the use of draglines and shovels working in tandem has made possible a higher stripping ratio of overburden to coal far beyond the ecomic limits of a decade ago. Improved drilling equipment and efficient blasting methods have obtained better fragmentation of the overlying rock, with the result that draglines with large buckets and long booms can dispose of much greater quantities of overburden per operation; in some instances it has been found economical to rehandle the overburden to make room for the spoil piles, and to reach dipping coal beds.

The tonnage of bituminous coal and lignite produced by stripping from 1930 to 1946, inclusive, is shown in table 29. In 17 years the coal production by this method has increased from 19,842,000 tons in 1930 to an estimated 109,000,000 tons in 1946.

The percentage of the total coal production produced by stripping has increased from 4.3 percent in 1930 to an estimated 19.0 percent in 1945 and 18.7 percent in 1946.

The number of men employed in coal-stripping operations has increased from 6,992 in 1930 to an estimated 33,569 in 1945. The increase in the number of men employed at strip coal mines, by years, is shown in table 30.

TABLE 29. - Production of bituminous coal and lignite

	Tonnage mined in 1,000's of tons			
Year	Underground workings	Strippings	Total	Percentage of total production mined by strippings
1930	447,684	19,842	467,526	4.3
1931	363,254	18,849	382,105	4.9
1932	290,068	19,640	309,710	6.3
1933	315,394	18,237	333,631	5.5
1934	338,576	20,792	359,368	5.8
1935	348,722	23,647	372,369	6.4
1936	409,251	27,218	436,468	6.2
1937	415,425	31,622	447,047	7.1
1938	319,242	30,305	349,548	8.7
1939	359,371	37,260	396,631	9.4
1940	418,960	42,358	461,319	9.2
1941	460,292	55,478	515,769	10.7
1942	516,222	65,482	581,705	11.2
1943	513,651	79,821	593,471	13.5
1944 1/	518,678	100,896	619,576	16.3
1945 1/	467,630	109,987	577,617	19.0
1946 1/	423,000	109,000	532,000	18.7

1/ From Coal Economics Division, Bureau of Mines.

TABLE 30. - Employment data for bituminous-coal and lignite mines

Year	Average number of workers employed			
	Underground workings	Strippings	Surface plants at underground mines	Total
1930	426,664	6,992	59,546	493,202
1931	387,693	6,259	56,322	450,274
1932	345,874	6,168	54,338	406,380
1933	352,915	7,058	58,779	418,752
1934	384,964	7,588	65,492	458,044
1935	389,978	8,493	63,883	462,354
1936	405,027	10,901	66,572	482,500
1937	413,136	11,695	65,940	490,771
1938	373,271	11,351	60,624	445,246
1939	370,791	12,848	61,405	445,044
1940	366,000	14,239	60,608	440,847
1941	374,953	18,605	64,186	457,744
1942	361,061	20,353	67,383	448,797
1943	318,776	23,044	65,315	407,135
1944	1/	1/	1/	2/380,000
1945	1/	1/	1/	2/363,000
1946	1/	1/	1/	2/379,000

1/ Not yet available.
2/ Preliminary.

The increase in this type of mining has increased the number of fatal and nonfatal accidents in that phase of coal mining; this is shown in table 31. The fatal-accident rate per million tons of coal produced by stripping has not definitely improved in the period 1930 to 1946; however, in the past 4 years the fatality rate per million tons of coal produced in bituminous-coal stripping has decreased each year from an all-time high of 0.61 in 1941 to an estimated 0.219 in 1945 and 0.201 in 1946. The nonfatal-injury rate in strip mining of coal since 1940 has decreased in 3 successive years from 31.611 in 1940 to 19.181 in 1943, which is the last year for which complete statistics are available (table 32). The improvement in accident rates covers too short a time to establish a definite trend, but greater vigilance is desirable even if the accident rates are maintained at only the present relatively favorable levels.

The man-hours worked at strip coal mines in the United States increased from 10,238,000 in 1930 to 407,000,000 in 1943, the last year for which complete statistics are available. The man-hours of exposure, by years, from 1930 to 1943, inclusive, are shown in table 33. The fatal- and nonfatal-accident rates per million man-hours of exposure are shown in table 34. The rate for fatal accidents in coal strippings has not shown much improvement in the period, although the rate has declined from a high of 1.144 in 1941 to an estimated 0,59 in 1944 and 0.42 in 1945. The nonfatal accident rates are available only through 1943; the rates shown in table 34 reveal a decline each year since 1936, when the rate for nonfatal injuries was 79.821, and in 1943 it was 37.610, a decline of 52.8 percent.

TABLE 31. - Number of accidents at bituminous-coal and lignite mines

Year	Underground workings		Strippings		Surface plants at underground mines		Total	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	1,546	65,775	10	872	63	4,570	1,619	71,217
1931	1,026	50,286	2	594	52	3,095	1,080	53,975
1932	895	35,923	11	766	52	2,663	958	39,352
1933	772	40,052	9	856	52	3,038	833	43,946
1934	894	42,846	8	725	56	3,411	958	46,982
1935	905	43,666	14	735	49	3,128	968	47,529
1936	1,034	46,402	15	1,208	49	2,904	1,098	50,514
1937	1,128	48,268	8	1,275	62	3,304	1,198	52,847
1938	623	33,392	18	1,036	39	2,066	880	36,794
1939	623	34,822	9	1,133	35	2,589	867	38,544
1940	1,136	39,695	22	1,339	46	2,959	1,204	43,994
1941	994	42,218	34	1,450	44	2,969	1,072	46,637
1942	1,143	48,267	31	1,460	71	3,466	1,245	53,193
1943	1,130	45,035	33	1,531	62	4,501	1,225	51,067
1944	1/1,051	2/	1/30	2/	1/39	2/	1/1,120	1/52,900
1945	1/854	2/	1/24	2/	1/58	2/	1/936	1/47,750
1946	1/734	2/	1/22	2/	1/44	2/	1/800	1/44,000

1/ Preliminary.
2/ Not yet available.

TABLE 32. - Accident rates based upon millions of tons produced at bituminous-coal and lignite mines

Year	Underground workings		Stripping		Total 1/	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	3.453	146.923	0.504	43.946	3.463	152.327
1931	2.824	138.432	.106	31.514	2.826	141.257
1932	3.085	123.843	.560	39.003	3.093	127.061
1933	2.448	126.991	.494	46.938	2.497	131.721
1934	2.640	128.548	.385	34.868	2.666	130.735
1935	2.595	125.217	.592	31.082	2.600	127.639
1936	2.527	113.363	.551	44.383	2.516	115.733
1937	2.715	116.189	.253	40.320	2.680	118.213
1938	2.578	105.537	.594	34.186	2.518	105.262
1939	2.290	96.897	.242	30.408	2.186	97.179

See footnote at end of table.

TABLE 32. - Accident rates based upon millions of tons produced at bituminous-coal and lignite mines (Cont'd.)

Year	Underground workings		Stripping		Total1/	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1940	2.711	94.749	0.519	31.611	2.610	95.366
1941	2.160	91.720	.613	26.137	2.078	90.422
1942	2.214	93.500	.473	22.296	2.140	91.443
1943	2.200	87.876	.413	19.181	2.064	86.048
1944	2/2.020	3/	2/.297	3/	2/1.807	2/85.380
1945	2/1.800	3/	2/.219	3/	1.620	2/82.667
1946	2/1.73	3/	2/.201	3/	1.504	2/82.707

1/ Includes injuries to surface workers of underground mines as well as to those in underground workings and strip mines.

2/ Preliminary.

3/ Not yet available.

TABLE 33. - Man-hours of exposure in bituminous-coal and lignite mines

Year	Man-hours worked, in thousands of hours			
	Underground workings	Strippings	Surface plants at underground mines	Total
1930	647,986	10,238	91,925	750,149
1931	510,366	9,101	76,512	595,950
1932	404,182	8,853	66,413	479,447
1933	474,127	9,286	81,012	564,425
1934	496,437	9,347	85,275	591,059
1935	485,437	11,444	81,725	578,511
1936	559,734	15,134	95,033	669,901
1937	565,071	17,528	92,970	675,568
1938	417,345	16,345	71,662	505,316
1939	457,965	18,682	78,337	554,984
1940	516,346	22,128	87,500	625,974
1941	563,236	29,712	98,101	691,049
1942	621,472	34,988	116,369	772,829
1943	610,834	40,707	126,429	777,970
1944	1/	1/	1/	2/839,000
1945	1/	1/	1/	2/762,000
1946	1/	1/	1/	2/730,000

1/ Not yet available.

2/ Preliminary.

TABLE 34. - Accident rates based upon millions of man-hours of exposure at bituminous-coal strippings

Year	Underground workings		Surface plants at underground mines		Strippings		Total	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	2.386	101.507	0.685	49.714	0.977	85.176	2.158	94.937
1931	2.010	98.529	.680	40.451	.220	65.270	1.812	90.565
1932	2.214	88.878	.783	40.098	1.243	86.527	1.998	82.078
1933	1.628	84.475	.642	37.501	.969	92.177	1.476	77.870
1934	1.801	86.307	.657	40.000	.856	77.566	1.621	79.486
1935	1.865	89.970	.600	38.274	1.223	64.228	1.673	82.157
1936	1.847	82.900	.516	30.558	.991	79.821	1.639	75.405
1937	1.996	85.419	.667	35.359	.456	72.741	1.773	78.226
1938	1.972	80.729	.554	28.830	1.104	63.523	1.741	72.814
1939	1.797	76.036	.447	33.049	.482	80.647	1.562	69.451
1940	2.200	76.879	.526	33.817	.994	60.512	1.923	70.281
1941	1.765	74.956	.449	30.265	1.144	48.802	1.551	67.487
1942	1.839	77.666	.610	29.785	.886	41.729	1.611	68.829
1943	1.850	73.727	.490	35.601	.811	37.610	1.575	65.641
1944	1/	1/	1/	1/	2/.590	1/	2/1.334	63.051
1945	1/	1/	1/	1/	2/.420	1/	2/1.228	2/62.664
1946	1/	1/	1/	1/	1/	1/	1.10	60.270

1/ Not yet available.
2/ Estimated.

The increase in tonnage of coal produced by stripping methods has favorably affected the fatal-accident record of the coal industry at large because of the comparatively low fatal-accident rate per million tons attained by the stripping procedures. Table 35 lists the total number of fatal accidents that occurred in the bituminous-coal and lignite industry, the fatal accidents that occurred in stripping, the percentage of stripping fatal accidents of the total fatal accidents that occur in the industry, and the percentage of total tonnage of coal mined by stripping methods.

A comparison of the percentage of fatal stripping accidents to total fatal accidents with the percentage of coal mined annually by stripping methods is revealing. In 1946 stripping produced an estimated 18.7 percent of the total bituminous-coal and lignite mined and was responsible for 2.75 percent of the total number of fatalities of the coal industry.

TABLE 35.--Fatal-accident data in bituminous-coal mines and in bituminous stripping operations

Year	Total	Stripping	Percentage of fatal accidents occurring in strip to all bituminous coal mining	Percentage of total bituminous coal tonnage mined by stripping
1930 ...	1,619	10	0.61	4.3
1931 ...	1,080	2	.18	4.9
1932 ...	958	11	1.15	6.3
1933 ...	853	9	1.08	5.5
1934 ...	958	8	.83	5.8
1935 ...	968	14	1.44	6.4
1936 ...	1,098	15	1.36	6.2
1937 ...	1,198	8	.66	7.1
1938 ...	880	18	2.04	8.7
1939 ...	867	9	1.04	9.4
1940 ...	1,204	22	1.83	9.2
1941 ...	1,072	34	3.17	10.7
1942 ...	1,245	31	2.49	11.2
1943 ...	1,225	33	2.69	13.5
1944 ...	1,120	30	2.68	16.3
1945 ...	936	24	2.58	19.0
1946 ...	800	22	2.75	18.7

Mechanical Loading of Coal

The use of mechanical loading devices to load coal underground has increased rapidly in the last several years; the tonnage loaded mechanically has increased approximately 550 percent since 1935. Installation of these mechanical devices has increased the output per man-hour but it has also increased the hazards of mining, or at least it has introduced new hazards, as any new equipment underground brings with it hazards that did not exist before installation of the equipment; in fact, every piece of mechanical equipment (even safety devices or equipment) taken into a mine introduces additional hazards, though it may eliminate or aid in the elimination or lessening of other hazards. For this reason a brief discussion of mechanical loading is appropriate, as it definitely affects the rate of accident in underground mining, particularly when comparisons are made with the years when mechanical loading was not as important as it is today.

The term "mechanized" is misleading unless it is definitely defined and understood. In this paper mechanically loaded coal is divided into two groups, (1) loaded by machine and (2) handled by conveyor. Loading by machine is subdivided into (1) mobile loading machines, (2) scrapers, and (3) conveyors equipped with duck bills or other self-loading heads. Tonnage handled by conveyors is subdivided into (1) pit-car loaders and (2) hand-loaded conveyors.

Table 36 shows the tonnage mined by each type of equipment for the period 1923 to 1945, inclusive. Much of the information contained in this table was compiled from statistics prepared by the Coal Economics Division of the Bureau of Mines, as indicated in the footnotes.

TABLE 36. - Twenty years of growth of mechanical loading at underground bituminous-coal and lignite mines1/

	Underground production, in 1,000's of tons						
	Loaded by machines				Handled by conveyors		
Year	Mobile loading machines	Scrapers	Conveyors equipped with duckbills or other self-loading heads	Total	Pit-car loaders	Hand-loaded conveyors	Total
1926	7,786	1,554	682	10,022	523	2/	2/
1927	2/	2/	2/	2/	2/	2/	2/
1928	11,811	1,548	1,200	14,559	4,117	2,883	7,000
1929	16,432	1,550	1,309	19,291	14,979	3,592	18,571
1930	20,073	1,637	1,628	23,338	19,116	4,528	26,644
1931	19,407	1,471	1,811	22,689	19,172	5,701	24,873
1932	14,825	1,132	1,630	17,587	12,590	5,640	18,230
1933	17,865	991	1,656	20,512	11,413	5,896	17,309
1934	20,750	1,004	2,082	23,836	11,089	6,508	17,597
1935	24,675	1,118	2,595	28,388	11,098	7,691	18,789
1936	40,970	1,273	3,240	45,483	10,538	10,956	21,494
1937	2/	2/	2/	2/	2/	2/	2/
1938	57,824	1,031	4,248	63,103	5,653	16,337	21,990
1939	76,442	1,007	6,759	84,208	5,038	21,466	26,504
1940	100,962	1,255	10,362	112,579	3,979	31,312	35,291
1941	126,478	1,290	14,918	142,686	3,447	40,534	43,981
1942	160,301	1,405	20,683	182,389	3,252	47,262	50,514
1943	179,008	1,349	22,917	203,274	2,669	43,862	46,531
1944	202,875	1,341	23,164	227,380	1,835	44,974	46,809
1945	198,668	1,252	21,506	221,426	986	40,100	41,086

1/ From Coal Economics Division, Bureau of Mines.
2/ Not available.

It is important to note the increase in tonnage of coal mined mechanically since 1923, the first year for which statistics of this type are available. In 1923, only 0.3 percent of the total tonnage was mined mechanically, but by 1945 the percentage had increased to 56.1 percent, or approximately 262,512,000 tons out of an estimated 467,630,000 tons total underground production in that year. The percentage of underground production of coal loaded mechanically, by years, since 1923 is shown in table 37.

Table 36 gives the increase in tonnage mined by mobile loading machines since 1926, when 7,786,000 tons were loaded, compared with 198,668,000 tons in 1945. The tonnage mined by scrapers has remained virtually uniform in the period, with only a slight reduction from 1,554,000 tons in 1926 to 1,252,000 tons in 1945.

TABLE 37. - Percentage of bituminous-coal and lignite underground production mechanically loaded

Year	Underground production, in 1,000's of tons		
	Total mechanically loaded[1]	Total underground production[2]	Percentage of underground production mechanically loaded
1923	[3]1,880	552,625	0.3
1924	[3]3,496	470,080	.7
1925	[3]6,243	503,182	1.2
1926	[3]10,545	556,444	1.8
1927	16,500	499,385	3.3
1928	21,559	480,956	4.5
1929	37,862	514,721	7.4
1930	46,982	447,684	10.5
1931	47,562	363,254	13.1
1932	35,817	290,068	12.3
1933	37,821	315,394	12.0
1934	41,433	338,576	12.2
1935	47,177	348,722	13.5
1936	66,977	409,251	16.4
1937	83,500	415,425	20.1
1938	85,093	319,242	26.7
1939	110,712	359,371	30.8
1940	147,870	418,960	35.3
1941	186,667	460,292	40.6
1942	232,903	516,222	45.1
1943	249,805	513,651	48.6
1944	274,189	518,678	52.9
1945	262,512	467,630	56.1

[1] From Coal Economics Division, Bureau of Mines.
[2] Data for 1923-1929 and 1944-1945 from Coal Economics Division.
[3] Exclusive of coal "handled by conveyors."

Loading coal with conveyor equipped with duckbills or other self-loading heads is second, in point of production, in the groups under "Loading by machines." Production with this type of equipment has doubled since 1940, when 10,362,000 tons were mined, to 21,506,000 in 1945.

The trend in mechanization of coal loading can be seen in table 38, which lists the loading units in actual use in the bituminous-coal and lignite mines in the period 1938 to 1945.

Rock Dusting in Bituminous-Coal and Lignite Mines

Table 39, which was taken from an unpublished report compiled by the Accident Analysis Division of the Bureau of Mines, gives the latest available data on the use of rock dust in the bituminous coal mines of the United States.

TABLE 38. - Number of mechanical loading units in actual use

Year	Mobile loading machines	Scrapers	Conveyors equipped with duckbills or other self-loading heads	Pit-car loaders	Hand loaded conveyors	All
1938	1,405	117	346	1,392	1,526	4,786
1939	1,573	131	559	873	1,834	4,970
1940	1,720	116	656	697	2,263	5,452
1941	1,985	109	788	607	2,807	6,296
1942	2,301	93	1,062	481	3,041	6,978
1943	2,525	83	1,226	321	3,191	7,346
1944	2,737	87	1,331	241	3,236	7,632
1945	2,950	87	1,383	142	3,385	7,947

This table shows that the number of mines employing rock dust had nearly doubled and that the quantity of rock duct applied to underground workings was four times greater in 1943 than in 1930. Although 16.3 percent of the underground mines (910 out of 5,624) reported or claimed to use rock dust, only a small percentage of these mines was adequately rock dusted, as some of the reports show that the amount of rock dust applied was so small that it would give little or no protection in case of a gas or dust explosion. The fact that mines using rock dust in 1943 represented only 16.2 percent of the underground coal mines, yet produced 66 percent of the production and employed 58 percent of the underground workers, indicates that it is chiefly the mines of large production that are using rock dust. Of the 674 mines classified as gassy by the inspection or mining departments of the various States, only 484, or 72 percent, used rock dust. These 484 mines used 82 percent of the total amount of rock dust applied in all mines and produced 89 percent of the coal coming from gassy mines. Having but 72 percent of the known gassy mines reporting the use of rock dust is a sad commentary on the attitude of far too many people in the coal-mining industry; it shows that although progress is being made, it is not keeping pace with what should be expected of the industry in the protection of either the employees or the mines. About 190 mines classified as gassy by their State authorities and producing nearly 68 million tons of coal have been making no attempt to safeguard life and property by the use of rock dust.

Although the number of mines using rock dust and the amount used have increased considerably in the past few years, rock-dusting does not adequately protect coal mines. Prior to 1939, the number of mines using rock dust and the quantity used fluctuated from year to year, fewer mines using rock dust than in 1930 (except in 1937), while the quantity decreased from 1930 to 1936. The greatest progress has occurred since 1939 both in the number of mines using dust and the amount of dust used. This increase was undoubtedly due largely to several gas and coal-dust explosions with heavy loss of life during 1940, which stimulated the use of rock dust. It was also partly due to the inaugaration of the Federal coal-mine inspection in 1941.

TABLE 39. - Summary of data for underground bituminous-coal mines in the United States using rock dust, 1930-1943

Year	Mines reported using rock dust	Production from mines using rock dust	Percentage of mines using rock dust	Percentage of total underground employees in mines using rock dust	Percentage of production from mines using rock dust	Rock dust used, pounds	Pounds of rock dust per ton of coal produced	Deaths from major explosions
1930 ...	474	148,634,912	8.4	27.5	33.2	137,738,000	0.93	225
1931 ...	449	115,904,819	8.3	26.8	31.9	119,621,000	1.03	56
1932 ...	393	88,632,327	7.5	25.7	30.6	74,938,000	.85	145
1933 ...	382	96,691,753	7.2	25.4	30.7	73,150,000	.76	7
1934 ...	407	112,455,110	6.8	28.3	33.2	103,234,000	.92	22
1935 ...	416	119,368,116	7.0	29.0	34.2	109,988,000	.92	35
1936 ...	460	161,039,698	7.4	32.5	39.3	142,818,000	.89	37
1937 ...	518	177,389,078	8.5	36.3	42.7	173,190,000	.98	101
1938 ...	431	126,635,677	7.2	33.2	39.7	144,430,000	1.14	84
1939 ...	526	174,907,275	7.9	40.0	48.7	182,334,000	1.04	28
1940 ...	599	233,243,276	9.1	46.5	55.1	281,472,000	1.21	276
1941 ...	678	262,946,534	10.2	49.4	57.1	344,604,000	1.31	73
1942 ...	838	328,621,730	13.5	55.6	63.6	521,110,000	1.59	132
1943 ...	910	339,329,147	16.2	58.4	66.1	549,972,000	1.62	179

Table 40, taken from the same source as table 39, gives a breakdown on the use of rock dust in various States during 1943 and also shows the pounds of rock dust used per ton of coal produced for 1930 and 1940 in some of the States.

Alabama uses more rock dust per ton of coal produced than any other State, using more than twice as much as the next closest State, Colorado. By using the pounds of rock dust per ton of coal produced as a basis, it can be seen that although many States have shown a marked increase since 1930, others have shown little progress, and some have shown a decrease.

TABLE 40. - Rock dusting in various States during 1943

State	Mines reported using rock dust	Rock-dust use-tons	Production from mines using rock dust	Percentage of total underground employees in mines using rock dust	Percentage of production from mines using rock dust	Pounds of rock dust used per ton of coal produced in mines using rock dust		
						1943	1940	1930
Alabama	59	36,848	13,655,938	76.0	79.4	5.39	2.64	1.81
Colorado ...	68	6,406	5,235,649	62.2	62.9	2.45	.93	1.37
Illinois ...	50	7,562	39,156,456	54.0	69.2	.37	.40	.42
Indiana	18	1,173	9,085,320	65.8	76.8	.26	.18	.41
Kansas	3	23	95,329	20.4	22.9	.47	-	-
Kentucky ...	68	9,355	27,581,506	39.7	45.5	.50	.57	.48
Montana	3	320	527,769	19.5	23.2	1.21	-	-
New Mexico..	16	1,676	1,489,902	68.0	79.7	2.25	2.41	2.16
Ohio	29	9,716	14,884,747	57.2	65.6	1.31	.39	.63
Oklahoma ...	4	109	141,466	15.2	10.0	1.54	-	-
Pennsylvania	142	59,964	81,048,716	60.1	65.3	1.48	.94	.97
Tennessee ..	8	282	1,212,687	16.5	16.6	.46	-	-
Utah	39	4,507	6,596,028	95.7	97.6	1.36	.88	1.40
Virginia ...	33	11,766	10,618,485	44.8	51.6	2.22	-	-
Washington..	5	312	786,785	45.4	48.3	.85	.64	.36
West Virginia ..	332	122,335	119,006,405	73.1	77.5	2.05	1.72	.91
Wyoming	26	2,518	7,704,792	87.3	85.8	.65	.62	1.12
Other States[1]...	7	114	511,167	10.3	16.0	.42	-	-

[1] Includes Arizona, Arkansas, and Maryland.

Utah appears to offer the best protection, in that rock-dusted mines comprise 97.6 percent of its production and 95.7 percent of its underground employees. For the year 1943, Utah, Wyoming, Alabama, and West Virginia, in the order named, are the ranking States in percentage of coal produced and number of employees working in rock-dusted mines.

Although data for 1944 to 1947 are not available, indications are that the total quantity of rock dust used increased yearly since 1943 and that more workers have been protected from the occurrence of widespread explosion disasters by rock dusting than at any other period in the history of the industry.

The figures for 1947 should show a decisive increase over any previous year owing to the closing of many mines following the Centralia disaster largely for lack of adequate rock dusting and the requirement that all mines should be adequately rock-dusted in order to be permitted to operate.

Unfortunately, it has taken a heavy toll of life to make many people of the coal-mining industry of the United States cognizant of the fact that rock dust limits or prevents widespread explosion disasters. The increased use of rock dust in several States, shown in table 40, resulted mainly from the use of additional rock dust following explosions within the State in which the increase occurred. This indicates shallow thinking and acting upon the part of those who work our coal mines, both operators and mine workers. It is a sad commentary on the safety-mindedness of those engaged in the industry, that attention to a major means of preventing widespread mine disasters is neglected until after a serious disaster occurs, and generally even here the subject is disregarded or "forgotten" within a few months after the disaster has passed into history. Adequate rock-dusting can be done and kept in effect for a few cents per ton of coal mined, and the industry cannot fail to make the expenditure and still retain its self respect. Rock dusting of bituminous-coal mines should be required just as are timbering, ventilation, handling, maintenance of machinery, etc.; and if rock dusting is to be effective, it should be done thoroughly and not merely given token consideration so as to pass muster when given a cursory inspection.

Effect of Thickness of Coal Beds upon Fatal-accident Rates

A study of the statistics of accidents that occur in underground bituminous-coal and lignite mines should include, among numerous other features, the effect of thickness of coal beds upon accident rates as well as the average time required to load a unit of coal. Mines in the so-called "low coal" and "high coal" have some very different problems and hazards, primarily because of roof conditions and ventilation problems.

Table 41 is a classification of the bituminous-coal and lignite mines for 1943 arranged in groups according to thickness of coal bed. The table shows the number of mines, number of employees, and production from each group, as well as the number of fatal and nonfatal injuries and the accident rates based upon millions of tons of coal mined and on millions of man-hours of exposure. Included in the table is the calculated average number of hours required to mine 1 ton of coal in the beds of various thickness and the tons of coal produced per man-hour of work.

Mines in coal beds 2 to 7 feet or more in thickness produced 98.4 percent of the bituminous and lignite in 1943, employed 97.0 percent of the total workers underground, and suffered 96.37 percent of the total number of fatal accidents.

TABLE 41. - Employment and accidents underground at bituminous-coal mines in the United States, classified according to the thickness of the coal bed, 1943

Thickness of coal bed, ft.	Mines	Employees	Man-hours of employment	Production, short tons	Percent of total production	Killed	Injured
0 to 2	158	3,146	5,281,333	1,750,830	0.34	7	205
2 to 3	891	28,480	52,370,279	31,388,950	6.11	96	3,687
3 to 4	1,495	84,161	163,463,957	120,892,059	23.53	258	12,530
4 to 5	1,015	65,353	125,367,727	101,663,793	19.79	215	9,787
5 to 6	710	49,813	95,737,203	85,399,793	16.63	156	7,185
6 to 7	347	38,512	75,122,262	76,423,923	14.89	237	4,967
Over 7	444	42,878	82,680,138	89,738,159	17.47	127	6,103
Not reported	564	6,433	10,811,225	6,393,331	1.24	34	571
	5,624	318,776	610,834,124	513,650,838	100.00	1,130	45,035

Thickness of coal bed, ft.	Rate per million man-hours		Rate per million tons		Tons per man-hour of work	Man-hours of work per ton
	Killed	Injured	Killed	Injured		
0 to 2	1.325	38.816	3.998	117.087	0.332	3.016
2 to 3	1.833	70.403	3.058	117.462	.599	1.668
3 to 4	1.578	76.653	2.134	103.646	.740	1.352
4 to 6	1.715	78.066	2.115	96.268	.811	1.233
5 to 6	1.629	75.040	1.827	84.134	.892	1.121
6 to 7	3.155	66.119	3.101	64.993	1.017	.983
Over 7	1.536	73.815	1.415	68.009	1.085	.921
Not reported	3.145	52.815	5.318	89.312	.591	1.691
	1.850	73.727	2.200	87.676	.841	1.189

Notwithstanding the widely varying conditions and methods used in mining "low coal" and "high coal," the thickness of the coal beds appears to have relatively little effect upon the occurrence of fatal accidents in underground mines. Considering the statistics for 1943 shown in table 41, the mines in beds 2 to 4 feet thick had 31.32 percent of the total fatal accidents and employed 35.3 percent of the total underground workers; mines in beds 4 to 6 feet thick had 32.83 percent of the total fatal accidents and employed 36.1 percent of the total personnel. Mines in beds 6 feet or more in thickness employed 25.5 percent of the total underground workers and had 32.22 percent of the total fatalities. Each group of mines killed approximately the same number of men. In 1942, the mines in coal beds 2 to 4 feet thick had 32.63 percent of the fatal accidents, mines in beds 4 to 6 feet thick had 32.42 percent, and mines in beds 6 feet or more in thickness had 29.65 percent.

The man-hours of exposure in producing coal from beds of various thickness vary considerably, as would be expected. The following tabulation shows the average number of man-hours required to load 1 ton of coal in beds of various thickness for 1942 and 1943:

Thickness of coal bed, feet	1942	1943
0 to 2	2.882	3.016
2 to 3	1.674	1.668
3 to 4	1.362	1.352
4 to 5	1.276	1.233
5 to 6	1.089	1.121
6 to 7	1.020	.983
Over 7	.931	.921
Not reported	1.659	1.691

The Problem of Small Mines

The number of workers employed underground and the tonnage of coal mined annually should not be the sole gage of the relative safety of coal mines. Although it is true that a small mine may be operating with an excellent safety record and a large mine may be very unsafe and have a decidedly poor accident record, nevertheless, in studying safety in coal mining, statistics reveal that the size of a mine in point of employment underground and the annual production have very definite effects upon the accident rates of the industry.

The number of small mines employing fewer than 25 men underground is larger than is commonly believed; in 1941, out of a total of 6,617 known bituminous-coal and lignite mines in the United States operating relatively continuously, 4,579, or 69.2 percent, employed 1 to 24 men underground; and in 1943 the percentage of a mine of this size was 65.8 percent, or 3,700 mines out of a total of 5,624 (table 42).

Mines employing 1 to 24 men mined 4.28 percent of the total bituminous-coal and lignite production in 1941 and 4.81 percent in 1943. The employment of underground workers in these mines was 7.93 percent of the total number of underground workers in the industry in 1941 and 8.28 percent in 1943.

The number of workers killed in mines employing 1 to 24 men in 1941 was 123, 101 in 1942, and 80 in 1943; in percentage of the total number killed in underground coal mines, this is 12.37 percent in 1941, 8.84 percent in 1942, and 7.08 percent in 1943. These and other relative statistics are shown in table 42.

Mines employing 1 to 9 men in 1941 numbered 3,552, or 53.6 percent of the total number of underground bituminous-coal and lignite mines; in 1942 there were 3,115 mines of this size, or 51.0 percent of the total, and 2,674 in 1943, or 47.5 percent of the total.

Mines employing 1 to 9 men mined only 1.88 percent of the total coal produced in 1941, 1.65 percent in 1942, and 1.71 percent in 1943. Employment in these mines underground amounted to 3.70 percent of the total underground employees in 1941, 3.32 percent in 1942, and 3.31 percent in 1943.

TABLE 42. - Bituminous-coal and lignite mines classified by the number of employees underground

Workers employed underground	1 to 24	25 to 99	100 to 199	200 to 399	400 to 599	600 and over	All
Mines:							
1941	4,579	1,014	472	359	119	74	6,617
1942	4,141	1,022	491	352	112	67	6,185
1943	3,700	933	469	326	88	48	5,624
Workers:							
1941	29,768	53,328	68,559	99,312	57,144	66,842	374,953
1942	27,527	53,775	70,392	97,276	53,776	58,776	361,061
1943	26,374	51,994	66,206	88,823	41,629	43,750	318,776
Coal production, in 1,000's tons:							
1941	19,689	50,239	83,587	141,326	82,455	82,995	460,292
1942	21,595	62,246	98,713	157,983	89,289	86,395	516,222
1943	24,716	71,357	109,042	168,723	73,049	66,764	513,651
Percentage of total production, bitiminous and lignite:							
1941	4.28	10.91	18.16	30.70	17.91	18.03	100.00
1942	4.18	12.06	19.12	30.60	17.30	16.74	100.00
1943	4.81	13.89	21.23	32.85	14.22	13.00	100.00
Fatal accidents:							
1941	123	121	196	287	149	118	994
1942	101	187	228	287	204	136	1,143
1943	80	249	263	312	126	100	1,130
Percentage of total fatalities:							
1941	12.37	12.17	19.72	28.87	14.99	11.87	
1942	8.84	16.36	19.95	25.11	17.85	11.90	
1943	7.08	22.04	23.27	27.61	11.15	8.85	

Fatal accidents in mines employing 1 to 9 men amounted to 82 in 1941, 62 in 1942, and 50 in 1943. Fatal accidents in mines of this size consitituted 8.27 percent of the total fatalities in bituminous coal mines in 1941, 5.42 percent in 1942, and 4.43 percent in 1943.

Carrying the analysis farther, mines employing 1 to 4 men constituted 35.7 percent of the total mines in 1941, employed 1.64 percent of the total underground workers, produced 0.82 percent of the total production of coal, but caused 5.03 percent of the total fatalities in underground coal mines. The percentage of the total number of fatalities occurring in mines of this size in 1941 was 5.03 percent, 3.67 percent in 1942, and 3.10 percent in 1943. These and other related statistics are shown in table 43.

TABLE 43. - Comparative fatal-accident statistics, small mines, compared with total mines

	Men employed underground in bituminous-coal and lignite mines					
	1 - 4	5 - 9	10 - 24	1 - 10	1 - 24	All mines
Mines:						
1941	2,370	1,182	1,027	3,552	4,579	6,617
1942	2,105	1,010	1,026	3,115	4,141	6,185
1943	1,733	941	1,026	2,674	3,700	5,624
Workers:						
1941	6,172	7,757	15,839	13,929	29,768	374,953
1942	5,462	6,534	15,531	11,996	27,527	361,063
1943	4,423	6,116	15,835	10,539	26,374	318,776
Coal production, in 1,000's tons:						
1941	3,786	4,882	11,021	8,668	19,689	460,292
1942	3,717	4,786	13,091	8,503	21,595	516,222
1943	3,335	5,430	15,951	8,765	24,716	513,651
Fatal accidents:						
1941	50	32	41	82	123	994
1942	42	20	39	62	101	1,143
1943	35	15	30	50	80	1,130
Percent of total fatalities:						
1941	5.03	3.24	4.13	8.27	12.37	-
1942	3.67	1.75	3.41	5.42	8.84	-
1943	3.10	1.33	2.65	4.43	7.08	-
Percent of total coal production:						
1941	.82	1.06	2.39	1.88	4.28	-
1942	.72	.93	2.53	1.65	4.18	-
1943	.65	1.06	3.11	1.71	4.81	-
Fatality rate per million tons:						
1941	13.21	6.55	3.72	9.46	6.25	2.16
1942	11.30	4.18	2.98	7.28	4.68	2.21
1943	10.50	2.76	1.88	5.70	3.24	2.20
Fatality rate per million man-hours:						
1941	7.20	3.45	1.99	5.05	3.34	1.76
1942	6.22	2.27	1.68	4.00	2.63	1.84
1943	6.00	1.62	1.14	3.32	1.91	1.85

Accident data relative to mines employing 1 to 4, 5 to 9, 10 to 24, 1 to 24, and 1 to 10 men are shown in table 43. The percentage of the total represented by each group of mines is shown, as well as other pertinent information.

By referring to tables 42 and 43, it is apparent that the larger mines have attained the lowest accident records during the period shown. Mines employing 600 or more men, although relatively few in number, produced 18.03

percent of the total tonnage of bituminous-coal and lignite mines in 1941 and 13.00 percent in 1943. Mines of this size caused 11.87 percent of the total number of fatalities in 1941 and 8.85 percent in 1943, but the fatality rates per million tons were 1.42 in 1941 and 1.50 in 1943. These compare with fatality rates per million tons in 1941 of 2.16 for the entire industry and 6.25 per million tons for mines employing 1 to 24 men, 9.45 for mines employing 1 to 9 men, and 13.21 for mines employing 1 to 4 men. In 1943 the fatality rate per million tons for all mines was 2.20, in mines employing 1 to 24 men it was 3.24, and 10.50 for mines employing 1 to 4 men.

The probable reason why larger mines have better safety records than small mines is that the larger mines are better able to supervise workers and working places and instruct workers, and also receive the benefits of more frequent State and Federal inspections. Of considerable importance, also, is the fact that the larger mines are better financed, as a rule; hence, they are able to furnish better and safer equipment and working conditions than the usual small mine. It is not unusual for small mines to fail to install and maintain up-to-date safe types of mining machinery and other safety devices for solely economic reasons; many of these small mines have only one opening, have no control of air flow, have primitive timbering and other unsafe procedures, and hence are inherently unsafe.

Bituminous-coal and lignite mines are classified in table 44 according to their annual production in 1941-1944. Mines producing less than 100,000 tons account for approximately 12 percent of the total annual coal production, but in 1941, 23.9 percent of the fatalities in coal mines occurred in mines that produced less than 100,000 tons annually, and in 1943 it was 18.1 percent. Fatal-accident rates, based upon millions of tons of coal produced and upon millions of man-hours of exposure, are far higher in mines with less than 100,000 tons annually than the average for all coal mines or for the various individual groups shown in table 44.

The smaller coal mines in the United States should be made at least as safe for the worker as the larger ones. State and Federal inspectors should inspect these small mines frequently, and employees and officials should be instructed as to the hazards of coal mining and how the hazards can be overcome entirely or at least to some degree. Small coal mines should receive more attention than they have received in the past, as they produce, roughly, 0.75 percent of the total annual tonnage of bituminous coal and lignite mines in the United States and employ about 1.50 percent of the underground workers, but they are responsible for about 3.5 percent of all underground fatalities.

Age of Miners

During the war most of the young men were removed from the mines by the draft and other influences, and in the last few years they have not been entering the mines in as great numbers as formerly, with the result that the average age of underground miners has increased considerably. Many occupations in underground mining require young, agile men who can move quickly if effective service is to be achieved and accidents are to be avoided; some of these are drivers, brakemen, rope riders, cage tenders, mining-machine operators, etc.

TABLE 44. - Underground bituminous-coal and lignite mines classified by annual tonnage of coal mined

	Annual production in short tons						
Size of mine	Less than 100,000	100,000 to 249,999	250,000 to 599,999	600,000 to 899,999	900,000 to 999,999	1,000,000 or more tons	All
Mines:							
1941	5,578	494	349	119	20	57	6,617
1942	5,069	518	366	134	23	75	6,185
1943	4,496	500	411	113	26	78	5,624
Employees:							
1941	88,047	72,361	99,276	55,613	12,809	46,847	374,953
1942	78,516	66,691	92,892	55,003	11,472	56,487	361,061
1943	65,329	55,311	93,686	43,693	9,485	51,272	318,776
Coal production, in 1,000's of tons:							
1941	60,039	81,822	135,987	85,299	18,938	78,207	460,292
1942	63,043	86,465	140,662	97,129	21,677	107,246	516,222
1943	63,148	80,806	156,109	81,653	23,591	108,344	513,651
Percentage of total production:							
1941	13.0	17.8	29.5	18.5	4.1	17.0	100.00
1942	12.2	16.8	27.2	18.8	4.2	20.8	100.00
1943	12.3	15.7	30.4	15.9	4.6	21.1	100.00
Fatal accidents:							
1941	238	193	290	154	28	91	994
1942	271	178	297	171	34	192	1,143
1943	204	292	337	115	35	147	1,130
Percentage of total fatalities:							
1941	23.9	19.4	29.2	15.5	2.8	9.2	100.00
1942	23.7	15.5	26.0	15.0	3.0	16.8	100.00
1943	18.1	25.8	29.8	10.2	3.1	13.0	100.00
Nonfatal injuries:							
1941	7,803	9,405	13,865	5,802	1,201	4,142	42,218
1942	8,100	10,667	14,438	7,050	1,608	6,404	48,267
1943	7,130	9,300	14,476	5,960	1,532	6,637	45,035
Percentage of total nonfatal injuries:							
1941	18.5	22.3	32.8	13.7	2.8	9.9	100.0
1942	16.8	22.1	29.9	14.6	3.3	13.3	100.0
1943	15.8	20.7	32.1	13.2	3.4	14.8	100.0
Fatal-accident rate per 1,000,000 tons:							
1941	3.96	2.36	2.13	1.81	1.48	1.16	2.16
1942	4.299	2.059	2.111	1.761	1.568	1.790	2.21
1943	3.231	3.614	2.159	1.408	1.484	1.357	2.20

TABLE 44. - Underground bituminous-coal and lignite mines classified by annual tonnage of coal mined (Cont'd.)

Size of mine	Annual production in short tons: Less than 100,000	100,000 to 249,000	250,000 to 599,999	600,000 to 899,999	900,000 to 999,999	1,000,000 or more tons	All
Nonfatal-injury rate per 1,000,000 tons:							
1941	129.97	114.94	101.96	68.02	63.42	52.96	91.72
1942	128.483	123.367	102.643	72.584	74.179	59.713	93.50
1943	112.910	115.090	92.730	72.992	64.939	61.259	87.68
Total man-hours employment in 1,000's of man-hours:							
1941	109,030	109,866	158,135	89.403	20,075	76,727	563,236
1942	113,399	116,284	164,764	100,323	21,675	105,045	621,472
1943	106,888	108,787	186,974	85,583	19,165	103,437	610,834
Fatal accidents per million man-hours:							
1941	2.18	1.76	1.83	1.72	1.39	1.19	1.76
1942	2.390	1.531	1.803	1.704	1.569	1.828	1.84
1943	1.909	2.684	1.802	1,344	1.826	1.421	1.85
Nonfatal injuries per million man-hours of exposure:							
1941	71.57	85.60	87.68	64.90	59.83	53.98	74.96
1942	71.429	91.732	87.638	70.273	74.185	60.964	77.67
1943	66.706	85.488	77.422	69.939	79.939	64.164	73.73

The decrease in number of vigorous, alert, young men in the coal mines of the United States has reached a serious stage, particularly in anthracite mines. High wages, relatively more comfortable living conditions, and less exacting work to be found elsewhere are more attractive to young men than coal mining; moreover, during the past several years mining has been a turbulent occupation, and returning soldiers and sailors usually desire peace rather than dissention.

The Social Security Bulletin issued in March 1947 published the following age statistics for the mining industry for 1944:

TABLE 45. - Age of employees in the mineral industry

	Metal			Nonmetallic	Crude petroleum	
Percentage	mining	Anthracite	Bituminous	Quarrying	Natural gas	All
Under 20 ...	4.8	1.8	3.8	8.8	8.7	5.3
20 to 24 ...	6.4	1.7	6.7	8.3	7.2	6.5
25 to 29 ...	12.0	7.7	10.2	9.1	10.1	10.1
30 to 34 ...	14.7	10.5	13.6	10.9	14.1	13.3
35 to 39 ...	14.1	15.2	12.8	14.0	13.8	13.5
40 to 44 ...	12.2	11.1	11.8	11.6	14.0	12.3
45 to 49 ...	10.5	10.5	11.2	10.8	11.3	11.1
50 to 54 ...	9.4	16.1	10.6	9.3	9.3	10.5
55 to 59 ...	8.7	12.8	10.0	6.8	5.6	8.8
60 to 64 ...	4.9	7.9	5.8	6.1	3.9	5.5
65 and over.	2.4	4.7	3.4	4.3	2.0	3.2
Total..	100.00	100.00	100.00	100.00	100.00	100.00
Median age..	39.3	46.0	41.2	39.6	38.6	40.5

The large percentage of workers in the upper age groups is startling, but the status of the mining industry with respect to the age of its workers appears even more startling when the same statistics are grouped as shown below:

				Nonmetallic	Crude petroleum	
Percentage	Metal	Anthracite	Bituminous	Quarrying	Natural gas	All
Under 25 ...	11.2	3.5	10.5	17.1	15.9	11.8
25 to 39 ...	40.8	33.4	36.6	34.0	38.0	36.9
40 to 49 ...	22.6	21.6	23.1	22.4	25.3	23.4
50 and over.	25.4	41.5	29.8	26.5	20.8	28.0
	100.0	100.0	100.0	100.0	100.0	100.0

The anthracite industry, with only 3.5 percent of its employees under 25 years of age and with 41.5 percent 50 or more years old, is likely to be in serious difficulty in the not far distant future in regard to manpower unless means are found to reverse the present trend. The bituminous-coal industry, with 10.5 percent of its employees under 25 years of age and 39.8 percent 50 or more years old, is in a position similar to the anthracite mining industry. Employment statistics for the entire coal industry reveal that approximately 63 percent of the employees are over 40 years old.

In work as strenuous and hazardous as mining, employment of older men in many occupations may result in increased occurrence of accidents, even though the more experienced worker should be able to protect himself better than younger and less experienced workers in many activities. The time required to train a new man in modern mining practices so that the new employee can be considered an experienced miner is considerable, and at present younger men are much less inclined to take the time and the hard and rather dirty work necessary to become safe, competent mine employees. The youth of today hasn't the patience his parents or grandparents had and is prone to desire to start at or close to the top rather than at or close to the bottom, which is very often necessary, especially in mining, if the fundamentals are to be mastered. The increased age of the mine worker in all types of mining deserves careful study, not only with respect to manpower but also safety and accidents.

It is evident from the preceding tabulation that those phases of the mining industry having chiefly surface activities, such as nonmetallic mining and quarrying, and the petroleum and natural-gas industries are attracting a much higher percentage of "under 25" recruits than are the sections of the industry engaged chiefly in underground work. Presumably, underground work is repulsive to the younger men, particularly in anthracite mining, where only 3.5 percent of the workers are under 25, as against 17.1 percent in nonmetallic mining and quarrying and 15.9 percent in crude petroleum and natural gas. With the relatively high pay now available in mining, especially coal mining, and the much better conditions as to health and safety in recent years, and the fact that climatic conditions (temperature, humidity, etc.) are in general better than in most types of surface work, it is difficult to understand the "standoffishness" of our young men in connection with entering coal and metal mines where there is now a definite demand for their services.

Some Examples of Good Safety Records at Bituminous-coal and Lignite Mines

Some remarkable no-fatality records have been established in underground bituminous-coal and lignite mines in the past 17 years. Not many years ago it was thought to be virtually impossible to mine one million tons of coal without a fatal injury, but a study of the nonfatality records of the Joseph A. Holmes Safety Association reveals that 394 awards have been given coal mines that have produced more than one million tons of coal without a fatality, and by no means all of the records of this type in bituminous-coal mining were placed before the association. The tonnages of coal produced at the mines for the periods of the awards are shown below:

Production, millions of tons	Number of awards
1 to 2	227
2 to 3	110
3 to 3-1/2	27
Over 3-1/2	40

A few examples of outstanding safety records are described briefly.

A hand-loading mine in Pennsylvania operated over 9 years without a fatal accident and produced 7,770,564 tons of coal. The man-hours of exposure totaled 10,451,396.

A mine in Illinois worked nearly 6 years without a fatal accident and produced 7,031,035 tons of coal. The mine was fully mechanized, and the man-hours of exposure totaled 5,175,835. The mine employed an average of 420 workers.

A mine in Wyoming operated nearly 17 years without a fatal accident and produced 5,220,209 tons of coal in the period. The mine is fully mechanized, and the coal bed ranges from 18 to 28 feet in thickness. An average of 192 men is employed.

A mine in Colorado worked over 18 years without a fatality and mined 3,586,434 tons of coal, the man-hours of exposure being 4,705,637.

A Pennsylvania mine operated over 21 years without a fatality and produced 4,095,087 tons of coal with 8,120,284 man-hours of exposure.

A West Virginia mine worked 34 months without a lost-time accident and produced 323,619 tons of coal; the exposure was 682,979 man-hours. This mine employed an average of 130 men.

Another West Virginia mine worked 30 months without a lost-time injury while producing 354,294 tons of coal; the exposure was 543,258 man-hours. The mine employed an average of 135 men; the coal was hand-loaded, and about 50 percent of the production was obtained from pillars.

A Virginia mine employing an average of 198 men worked 15-1/2 months without a lost-time accident while producing 231,469 tons of coal, the exposure being 509,232 man-hours.

A Wyoming mine produced 479,042 tons of coal in 16-1/2 months without a lost-time accident. The mine employed an average of 259 men, and the exposure was 501,462 man-hours.

A Kentucky mine produced 382,710 tons of coal in a 12-month period without a lost-time accident. The exposure was 381,426 man-hours to an average force of 243 men.

A Colorado mine employing an average of 75 workers during a period of 24 months produced 76,919 tons of coal without a lost-time accident, the exposure being 170,864 man-hours.

Safety records such as those mentioned above clearly show what can be done to make coal mines safer places in which to work. When mines, both large and small, can be operated for years without fatal accidents while producing several million tons of coal or can work a year or more without a lost-time accident, it is clearly evident that our coal mines can be made safer if safe practices and safe equipment are employed by management and workers. However, the sincere full-time cooperation of management and workers is essential if even relatively reasonable safety is to be achieved in the coal mines of the United States. Anything less than sincere continued cooperation of those engaged in the production of coal is almost certain to result in the occurrence of accidents, some which are likely to be fatalities, and occasionally there will be major disasters.

ANTHRACITE

Anthracite is included with bituminous coal and lignite in many discussions under the general term "coal or coal mines;" however, for accident-statistics purposes and for certain types of safety comparisons it is desirable that anthracite mines be considered separate from bituminous-coal and lignite mines. The anthracite mines, nearly all of which are now in

Pennsylvania, have many essential differences when compared with most bituminous-coal and lignite mines, insofar as mining methods, mining conditions, and mining problems are concerned, and in many particulars anthracite mines closely resemble some types of metal mines; in fact, some anthracite mines have problems more nearly like those of noncoal mines than of the usual run of coal mines.

Many of the anthracite beds are folded and faulted, and they range in thickness from very thin (3 feet or less) to very thick (up to 50 or more feet). The beds dip steeply at some mines and are almost flat at others, and some mines have essentially all degrees of pitch; at one mine, 13 different anthracite beds are mined through one hoisting shaft. Obviously, the mining problems differ from those encountered in mining one coal bed as at many bituminous-coal or lignite mines.

The different anthracite beds have varying characteristics, such as the percentage of ash, hardness, and B.t.u. content. Anthracite from the various beds usually is mixed in definite proportions at the preparation plants, commonly called breakers, and by this procedure the output, as placed on the market, is reasonably uniform as to both size and composition. This usually necessitates controlled mining from each bed of anthracite, which often complicates the mining problems. Extensive rock tunnels must be driven in many mines to connect the various anthracite beds for haulage and ventilation purposes, and this causes them to have both safety and health problems analogous to those of noncoal mines. Anthracite mines are deeper then most bituminous-coal and lignite mines, and this entails handling problems not met in most nonanthracite coal mines.

Much of the tonnage of anthracite produced in recent years is obtained by removing pillars or, as commonly expressed, by second or third mining. Operating under these conditions, especially where the strata are deeply pitching or are faulted or contorted or where the coal bed is thick is almost certain to be much more hazardous than the original mining in virgin coal as much of the present production is obtained from places contiguous to old workings, some of which are inaccurately mapped and are inaccessible and impossible to ventilate efficiently so as to keep them clear of accumulations of explosive or irrespirable gases. Abandoned mines or parts of mines frequently contain large quantities of explosive gas mixtures, atmosphere deficient in oxygen, or water, and these constitute a definite hazard to adjoining mines or parts of mines. Keeping operating mines reasonably free of water is one of the major items of the mining cost and adds materially to the problem of accident prevention.

The annual production of anthracite has decreased from approximately 90,000,000 tons in the period 1910-1924, inclusive, to around 60,000,000 tons or less in recent years. Table 46 shows the tonnage of anthracite mined each year since 1910, the number of fatal accidents, and the fatality rates per million tons and per million man-hours.

TABLE 46. - Data on anthracite production and accident rates

Year	Average number of men employed	Short tons produced, in 1,000's of tons	Fatal accidents	Fatality rates	
				Per million man-hours	Per million tons
1910	169,497	84,485	601	1.720	7.114
1911	173,940	90,464	699	1.815	7.727
1912	174,030	84,362	601	1.661	7.124
1913	175,745	91,525	618	1.520	6.752
1914	179,679	90,822	595	1.502	6.551
1915	176,552	88,995	586	1.603	6.585
1916	159,869	87,578	555	1.663	6.337
1917	154,174	99,612	582	1.656	5.843
1918	147,121	98,826	551	1.598	5.575
1919	154,571	88,092	635	1.931	7.208
1920	145,074	89,598	491	1.561	5.480
1921	159,499	90,473	547	1.582	6.046
1922	156,849	54,683	300	1.583	5.486
1923	157,743	93,339	509	1.505	5.453
1924	160,009	87,927	496	1.414	5.641
1925	160,312	61,817	400	1.714	6.471
1926	165,386	84,437	453	1.403	5.365
1927	165,259	80,096	489	1.644	6.105
1928	160,681	75,348	447	1.602	5.932
1929	151,501	73,828	482	1.767	6.529
1930	150,804	69,385	444	1.758	6.399
1931	139,431	59,646	383	1.838	6.421
1932	121,243	49,855	249	1.587	4.994
1933	104,430	49,541	231	1.493	4.663
1934	108,382	57,168	268	1.502	4.688
1935	102,848	52,263	274	1.778	5.243
1936	102,082	54,670	244	1.559	4.463
1937	99,085	51,745	215	1.583	4.155
1938	96,282	46,149	225	1.942	4.876
1939	94,331	51,346	211	1.713	4.109
1940	92,420	51,489	184	1.503	3.574
1941	88,948	54,115	194	1.491	3.585
1942	82,064	58,316	226	1.643	3.875
1943	79,381	59,506	226	1.498	3.798
1944[1]	77,500	63,195	174	1.074	2.853
1945[1]	74,000	54,674	143	1.000	2.616
1946[1]	77,000	60,685	174	-	2.867

[1] Preliminary.

The fatality rates based upon millions of tons and millions of man-hours for the entire industry show a marked decrease over the years; the fatality rate per million tons in 1910 was 7.114, and the estimated rate in 1943 was 2.867. The fatality rate per million man-hours in 1910 was 1.720, whereas the estimated rate was 1.000 in 1945 and 1.074 in 1944.

The total employment in the anthracite industry, by years, since 1910 is shown in table 46, but the data on underground employment are available only since 1930, the first year the Bureau of Mines collected fatal- and nonfatal-injury statistics from all coal mines (table 47). It should be noted that the employment of washery and dredge operations was included with stripping operations in the period 1930-35, but from 1936 to 1944 this employment was included under surface works at underground mines. The decrease in employment in the anthracite industry from 169,479 in 1910 to an estimated 74,000 in 1945 and 77,000 in 1946 roughly follows the decrease in anthracite production in the same period.

TABLE 47. - Average number of workers employed in anthracite mines

Year	Underground workings	Surface works	Stripping	Total
1930	118,832	28,902	1/3,070	150,804
1931	109,280	27,919	1/2,232	139,431
1932	94,210	24,721	1/2,312	121,243
1933	79,329	21,525	1/3,576	104,430
1934	82,372	21,680	1/4,330	108,382
1935	77,629	20,975	1/4,244	102,848
1936	76,128	2/21,041	4,667	102,082
1937	74,422	2/20,187	4,476	99,085
1938	72,360	2/20,291	3,361	96,282
1939	69,869	2/20,090	4,372	94,331
1940	68,639	2/18,888	4,893	92,420
1941	65,583	2/18,864	4,501	88,948
1942	58,747	2/18,957	4,360	82,064
1943	55,590	2/19,202	4,589	79,381
1944	-	-	-	3/77,500
1945	-	-	-	3/74,000
1946	-	-	-	3/77,000

1/ Includes washery and dredge operations.
2/ Includes surface operations at underground mines and washery and dredge operations.
3/ Preliminary.

The number of fatal and nonfatal accidents that occurred in the anthracite industry in the period 1930-1946 is shown in table 48. The accidents are classified into those occurring at underground workings, surface works or plants at underground mines, and stripping operations; again, however, the accidents that occurred at washery and dredge operations in the period 1930-1935 are included with stripping accidents, but from 1936 to the present they are included with surface works.

TABLE 48. - Number of accidents at anthracite mines

Year	Underground workings		Surface work		Stripping		Total	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930 ...	404	25,896	32	2,659	1/8	1/209	444	28,764
1931 ...	352	21,307	26	2,505	1/5	1/171	383	23,983
1932 ...	235	14,892	10	1,941	1/4	1/98	249	16,931
1933 ...	204	11,599	23	3,210	1/4	1/374	231	15,183
1934 ...	238	15,827	26	2,363	1/2	1/388	268	18,577
1935 ...	239	13,372	23	1,955	1/12	1/570	274	15,897
1936 ...	222	14,372	2/14	2/2,160	8	494	244	17,026
1937 ...	190	11,815	2/19	2/1,349	6	248	215	13,412
1938 ...	204	11,396	2/12	2/1,272	9	174	225	12,842
1939 ...	191	11,492	2/13	2/1,581	7	156	211	13,229
1940 ...	172	12,033	2/7	2/1,598	5	151	184	13,782
1941 ...	172	12,641	2/16	2/1,607	6	172	194	14,420
1942 ...	210	11,866	2/12	2/1,580	4	135	226	13,581
1943 ...	197	11,524	2/23	2/1,673	6	330	226	13,527
1944 ...	-	-	-	-	-	-	3/174	3/13,000
1945 ...	-	-	-	-	-	-	3/143	3/11,600
1946 ...	-	-	-	-	-	-	3/174	3/13,000

1/ Includes stripping, washery, and dredge operations.
2/ Includes surface operations at underground mines and washery and dredge operations.
3/ Preliminary.

The source of production of anthracite since 1930 is shown in table 49. Production from washery and dredge operations was included with stripping work from 1930 to 1935, but, beginning with 1936, the production obtained from washery and dredge operations is segregated. The importance of stripping, washery, and dredge operations in the total production of anthracite, especially in recent years, should be noted; in 1943 approximately 30 percent of the total anthracite production was obtained from these sources; evidently, production from underground operations in the anthracite region continues to fall off markedly, and the causes for this should be sought and overcome.

Table 50 shows the man-hours of exposure, in thousands of man-hours, from 1930 to the present. The surface works included the tipple, breaker, shops, and yards at underground mines for the period 1930-1935, but washery and dredge operations from 1936 to the present are included.

It is difficult to classify the various anthracite operations in the way that bituminous-coal and lignite data are classified; production from underground mines frequently goes to central breakers or preparation plants that

that handle the mine-run product from several underground mines as well as the product from stripping and bank or waste-pile operations.

TABLE 49. - Production of anthracite, in thousands of short tons

Year	Underground workings	Stripping	Total fresh-mined anthracite	Percent stripping	Washery and dredge	Total anthracite production
1930	64,926	[1]4,459				69,385
1931	53,465	[1]6,181				59,646
1932	43,826	[1]6,029				49,855
1933	40,965	[1]8,576				49,541
1934	48,575	[1]8,594				57,168
1935	43,783	[1]8,480				52,263
1936	44,727	6,203	50,930	12.2	3,740	54,670
1937	42,566	5,696	48,262	11.8	3,483	51,745
1938	38,142	5,095	43,237	11.8	2,912	46,149
1939	42,572	5,486	48,058	11.4	3,288	51,346
1940	41,511	6,146	47,657	12.9	3,832	51,489
1941	41,727	7,211	48,938	14.7	5,177	54,115
1942	44,339	9,027	53,366	16.9	4,950	58,316
1943	42,616	9,371	51,987	18.0	7,519	59,506
1944	-	-	-	-	-	63,592
1945	-	-	-	-	-	54,674
1946	-	-	-	-	-	60,282

[1] Includes coal from washeries and dredges.

TABLE 50. - Man-hours of exposure at anthracite mines, in thousands of hours

Year	Underground workings	Surface works[1]	Stripping[2]	Total
1930	199,068	48,667	4,807	252,543
1931	159,685	44,892	3,837	208,415
1932	119,218	34,063	3,663	156,944
1933	115,473	33,590	5,661	154,723
1934	134,351	37,057	6,964	178,372
1935	114,755	31,833	7,509	154,096
1936	115,556	33,102	7,503	156,486
1937	101,568	28,310	5,976	135,854
1938	86,549	24,587	4,716	115,852
1939	91,366	26,659	5,187	123,211
1940	90,512	25,830	6,105	122,447

See footnotes at end of table.

TABLE 50. - Man-hours of exposure at anthracite mines, in thousands of hours (Cont'd.)

Year	Underground workings	Surface works[1]	Stripping[2]	Total
1941	95,790	28,150	6,167	130,107
1942	99,439	31,499	6,622	137,560
1943	105,259	37,842	7,731	150,832
1944	-	-	-	3/162,000
1945	-			3/143,000

[1] Data for 1930-35 include only surface operations (tipple, breaker, shops, and yards) at underground mines; data for 1936-43 include surface operations at underground mines, and washery and dredge operations.

[2] Data for 1930-35 include stripping, washery, and dredge operations; data for 1936-43 include only stripping operations.

[3] Preliminary.

Table 51 and 52 show the fatal- and nonfatal-injury rates based upon millions of tons and millions of man-hours of exposure from 1930 to the present. The accident rates for underground workings decreased materially during the period; fatal accidents per million tons decreased from 6.222 in 1930 to 4.623 in 1944, and nonfatal injuries from 398.853 in 1930 to 270.418 in 1943. Total fatal accidents in the same period decreased from 6.399 per million tons in 1930 to an estimated 2.867 in 1946; nonfatal injuries decreased from 414.557 in 1930 to an estimated 214.221 in 1946. The larger decrease in the total fatal-accident rates for the period, compared with the decrease in rates for underground workings, is noticeable; the total fatal accident rate for 1930 was 6.399, and in 1946 it was 2.867, a reduction of 55.2 percent, whereas the rate for fatalities at underground workings decreased only 25.7 percent in 1943. This is due largely to the influence of the increased proportion of the total tonnage brought about by the increased tonnage obtained from stripping and dredge operations.

The injury rates, both fatal and nonfatal, when based upon millions of man-hours of exposure (table 52), show a marked decrease in the total fatal-accidents rates, which were 1.758 in 1930 and an estimated 1.000 in 1945, a decrease of 43.2 percent. The nonfatal-injury rates decreased from 113.898 in 1930 to an estimated 81.119 in 1945, or 28.8 percent. The decrease in both fatal- and nonfatal-injury rates is attributable largely to the influence of stripping, washery, and dredge operations.

TABLE 51. - Accident rates based upon millions of tons produced at anthracite mines

Year	Underground workings		Stripping		Total 1/	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	6.222	398.853	2/1.794	2/46.874	6.399	414.557
1931	6.584	398.524	2/.809	2/27.669	6.421	402.091
1932	5.362	339.798	2/.663	2/16.254	4.994	339.603
1933	4.980	283.140	2/.466	2/43.611	4.663	306.471
1934	4.900	325.828	2/.465	2/45.150	4.688	324.953
1935	5.459	305.416	2/1.415	2/67.217	5.243	304.174
1936	4.963	321.331	1.290	79.635	4.463	311.430
1937	4.464	277.567	1.053	43.539	4.155	259.192
1938	5.348	298.776	1.766	34.149	4.876	278.272
1939	4.487	269.946	1.276	28.434	4.109	257.646
1940	4.144	289.877	.814	24.571	3.574	267.666
1941	4.122	302.942	.832	23.851	3.585	266.470
1942	4.736	267.618	.443	14.956	3.875	232.886
1943	4.623	270.418	.640	35.216	3.798	227.323
1944	-	-	-	-	2.753	3/205.714
1945	-	-	-	-	2.616	3/212.168
1946	-	-	-	-	2.867	3/214.221

1/ Includes injuries to surface workers at underground mines, strippings, and washery and dredge operations.

2/ Includes stripping, washery, and dredge operations.

3/ Preliminary.

TABLE 52. - Accident rates based upon millions of man-hours of exposure at anthracite mines

Year	Underground workings		Surface works 1/		Stripping		Total	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	2.029	130.086	0.658	54.637	2/1.664	2/43.475	1.758	113.898
1931	2.204	133.431	.579	55.801	2/1.303	2/44.564	1.838	115.074
1932	1.971	124.914	.294	56.983	2/1.092	2/26.753	1.587	107.879
1933	1.767	100.448	.685	95.564	2/.707	2/66.072	1.493	98.130
1934	1.771	117.804	.702	63.740	2/.574	2/55.711	1.502	104.147
1935	2.083	116.527	.723	61.414	2/1.598	2/75.911	1.778	103.163
1936	1.921	124.372	.423	65.253	1.066	65.838	1.559	108.802
1937	1.871	116.326	.671	47.650	1.004	41.503	1.583	98.724
1938	2.357	131.672	.488	51.734	1.908	36.893	1.942	110.848
1939	2.091	125.780	.488	59.305	1.350	30.077	1.713	107.368
1940	1.900	132.943	.271	61.866	.819	24.735	1.503	112.555

See footnotes at end of table.

TABLE 52. - Accident rates based upon millions of man-hours of exposure at anthracite mines (Cont'd.)

Year	Underground workings		Surface works[1]		Stripping		Total	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1941	1.796	131.966	0.568	57.087	0.973	27.888	1.491	110.832
1942	2.112	119.329	.381	50.160	.604	20.388	1.643	98.728
1943	1.872	109.482	.608	44.210	.776	42.685	1.498	89.683
1944	-	-	-	-	-	-	[3]1.074	[3]80.247
1945	-	-	-	-	-	-	[3]1.000	[3]81.119

[1] Data for 1930-35 include only surface operations (tipple, breaker, shops, and yards) at underground mines; data for 1936-43 include surface operations at underground mines, and washery and dredge operations.

[2] Includes stripping, washery, and dredge operations.

[3] Preliminary.

Fatal Accidents Underground at Anthracite Mines by Principal Causes

The three principal causes of fatal accidents underground at anthracite mines in the relative order of their importance are falls of roof and coal, haulage, and explosives. The proportion of the total fatal accidents underground for each of these causes for the period 1941-1943 is shown below:

Percentage of total fatal accidents underground

	1941	1942	1943
Falls of roof and coal	58.1	63.3	56.8
Haulage	15.7	17.6	18.3
Explosives	7.0	6.2	4.6
	80.8	87.1	79.7

Roughly, 80 percent of fatal accidents underground at anthracite mines are due to these three causes. Causes designated explosions of gas, electricity, and shafts are the next three important causes of fatal accidents underground, varying in rank from year to year. It is significant that explosives as a cause of accidents in anthracite mines supplant explosions of gas or dust as the third highest cause of accidents in bituminous mines.

Table 53 lists the fatal accidents in the period 1941-1944, classified into principal causes, and shows the fatality rate based upon millions of tons of anthracite mined; table 54 shows the same classification of fatal injuries, but the fatal-accident rates are based upon millions of man-hours of exposure.

Falls of roof and coal

The largest single cause of fatal accidents at anthracite mines is falls of roof and coal; each year more men are killed from such falls than from all other causes combined. In this the anthracite mines follow the pattern of bituminous-coal and lignite mines, where uniformly, year by year for the past 2 decades, falls of roof and coal have caused more than 50 percent of the fatal accidents.

TABLE 53. - Fatal accidents at anthracite mines, by principal causes.
Rates based upon millions of tons

	1941		1942		1943	
Principal causes	Killed	Rate per million tons	Killed	Rate per million tons	Killed	Rate per million tons
Falls of roof and coal....	100	2.43	132	2.98	112	
Haulage	27	.65	37	.83	36	
Handling materials	3	.07	2	.05	3	
Hand tools	0	-	0	-	1	
Falls of persons	3	0.07	0	-	5	
Machinery	0	-	1	0.02	3	
Electricity	5	0.12	6	.14	2	
Explosives	12	.29	13	.29	9	
Explosions of gas	8	.19	9	.20	15	
Mine fires	0	-	5	.11	1	
Suffocation by natural gas	1	0.02	2	.05	1	
Shaft	6	.14	1	.02	5	
Falling material not being handled by injured	3	.09	1	.02	1	
Other	4	.09	1	.02	1	
Total underground....	172	4.122	210	4.736	197	
Surface works	6		4	-	23	
Stripping	16	.832	12	0.443	6	
Total	194	3.585	226	3.875	226	

TABLE 54. - Fatal accidents at anthracite mines, by principal causes.
Rates based upon millions of man-hours

	1941		1942		1943	
Principal causes	Killed	Rate per million man-hours	Killed	Rate per million man-hours	Killed	Rate per million man-hours
Falls of roof and coal....	100	1.044	132	1.327	112	1.064
Haulage	27	.282	37	.372	36	.342
Handling materials	3	.031	2	.020	3	.029
Hand tools	0	-	0	-	1	.009
Falls of persons	3	0.031	0	-	5	.047
Machinery	0	-	1	0.010	3	.029
Electricity	5	0.052	6	.060	2	.019
Explosives	12	.125	13	.130	9	.086
Explosions of gas	8	.084	9	.090	15	.143
Mine fires	0	-	5	.050	1	.009
Suffocation by natural gas	1	0.010	2	.020	1	.009
Shaft	6	.063	1	.010	5	.048
Falling material not being handled by injured	3	.031	1	.010	3	.029
Other	4	.042	1	.010	1	.009
Total underground ...	172	1.796	210	2.112	197	1.872
Surface works	6	.568	4	.381	23	.608
Stripping	16	.973	12	.604	6	.776
Total	194	1.491	226	1.643	226	1.498

Falls of roof, falls of face or rib, and rushes of rock, coal, or gob are the main items classified under falls of roof and coal; their relative importance in the period 1941-1943 is shown below:

	Number of persons killed	
	1941	1942
Falls of roof (rock, coal, slate)	72	110
Falls of face or rib	19	13
Rush of coal, rock, or gob	9	8
Roof fall due to machine knocking out prop.	0	1
	100	132

The records indicate that only by closer inspection of the roof of the mine workings and more intensive and prompt timbering can the larger part of this cause of fatal accidents be reduced. Falls of face or rib, particularly when mining in heavy ground, especially in pitching beds or in high coal, are likely to occur, especially in remining; and only agile, skillful, and careful miners should be employed at this type of work, which is certain to continue to be hazardous irrespective of precautions taken.

Haulage

The second main cause of fatal accidents underground at anthracite mines is haulage; approximately 15 to 18 percent of all fatal accidents in underground anthracite mines can be attributed to haulage, which roughly parallels the situation in bituminous mines. About 25 percent of the fatal haulage accidents occur while operating or riding a trip, which indicates the need for more clearance for trips; definitely safe equipment is seldom provided for man-trips insofar as making it impossible to touch the roof, rib, or trolley wire. Money spent to provide completely enclosed cars for man-trips is money well spent, provided their use is demanded. Transportation men should be agile and quick-thinking, safety rules for haulage should be comprehensive and strictly enforced, and haulage equipment and track should be kept in good repair at all times. The responsibility for haulage accidents is definitely a dual one, both workers and management being involved.

Explosives

The third main cause of fatal accidents underground at anthracite mines is explosives; the number of workers killed annually by blasting in the period 1941-1944 amounted to a relatively small percentage of the total number killed underground, but each year accidents from this cause occur, many of which are readily preventable.

Improper charging and tamping of drill holes, drilling into unexploded charges of explosives, and shots breaking through into adjoining workings are the principal causes of this class of accident. Many miners persist in handling explosives in an unsafe manner, and extensive and continuous education of miners and supervisors in safe methods of handling and using explosives is needed. The adoption of electric blasting by many mines has removed some causes of blasting accidents, but no form of blasting procedure is foolproof, and electric blasting has hazards of its own, which must be kept in mind and overcome.

Underground Workings

Much of the anthracite from underground workings is obtained from pillars and remnants left during the first, second, or even third mining; and the hazards of this type of work, especially in steep pitches, are reflected in the injury rates shown in table 55. Production of anthracite during the period 1930-1943 ranged from 64,926,000 tons in 1930 to 42,616,000 tons in 1943; employment in the same period in underground workings ranged from 118,832 in 1930 to 55,590 in 1943. The number of fatal injuries in 1930 was 404, and in 1943 it was 197. In 1940 and 1941 only 172 fatalities occurred in underground anthracite workings.

TABLE 55. - Accident data for underground workings at anthracite mines

	Number of injuries		Injury rates			
			Per million tons		Per million man-hours	
Year	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1930	404	25,896	6.222	398.853	2.029	130.086
1931	352	21,307	6.584	398.524	2.204	133.431
1932	235	14,892	5.362	339.798	1.971	124.914
1933	204	11,599	4.980	283.140	1.767	100.448
1934	238	15,827	4.900	325.828	1.771	117.804
1935	239	13,372	5.499	305.416	2.083	116.527
1936	222	14,372	4.963	321.331	1.921	124.372
1937	190	11,815	4.464	277.567	1.871	116.326
1938	204	11,396	5.348	298.776	2.357	131.672
1939	191	11,492	4.487	269.946	2.091	125.780
1940	172	12,033	4.144	289.877	1.900	132.943
1941	172	12,641	4.122	302.942	1.796	131.966
1942	210	11,866	4.736	267.618	2.112	119.329
1943	197	11,524	4.623	270.418	1.872	109.482

The fatality rates for underground workings, based upon millions of tons, was 6.222 in 1930 and 4.623 in 1943; and the fatality rate, based upon millions of man-hours of exposure, in 1930 was 2.029 and in 1943 it was 1.872. The statistics show some improvement in the fatality rates, but it has been slow and erratic. The nonfatal-injury rates based upon both millions of tons and on millions of man-hours of exposure from 1930 to 1943, inclusive, are shown in table 55. Unquestionably, the operation of anthracite mines, especially those having multiple veins and varying degrees of pitch, is almost certain to be much more costly in life and limb, as well as dollars and cents, than can be expected and realized in the usual type of bituminous-coal and lignite mines if the coal dust-explosion hazard is excepted.

Anthracite Stripping

The anthracite stripping work of Pennsylvania now produces a substantial proportion of the total tonnage of anthracite mined annually; in 1943 strippings produced 18 percent of the total tonnage, compared with 11.4 percent in 1939 and 12.2 percent in 1936. It is only within recent years that anthracite stripping tonnage has been important, and for this reason stripping statistics are of particular interest.

The problems confronting the operators in anthracite stripping are largely different from those of bituminous-coal and lignite stripping, and the statistics of the two classes of stripping are not strictly comparable. The anthracite beds usually are folded and at times form relatively shallow basins, wherein the ratio of overburden to anthracite is sufficiently low to make it feasible to strip the basin; or the outcrops of the anthracite beds are stripped and mined down the dip of the beds as deep as is feasible. At other places, local areas are stripped by contractors on the basis of a certain price per mine car of anthracite delivered at the breaker in place of a yardage contract. Some stripping is company-operated, at others the overburden is removed by stripping contractors and the anthracite is mined by the mining company, and at still other stripping workings both the anthracite and overburden are removed by the contractor.

The overburden at most anthracite stripping is largely rock, which must be drilled and blasted before it can be excavated (this is often not the case in bituminous-coal and lignite stripping, where in many places only a relatively small proportion of the overburden is rock which requires blasting).

The equipment used in stripping anthracite includes almost every type of shovel and dragline, ranging from the small gasoline or Diesel-powered types to the very large electric shovels and draglines commonly used in extensive bituminous-coal and lignite stripping. Trucks are now in common use to transport the anthracite and in some instances the overburden; a few years ago virtually all large-scale stripping work had rail transportation.

The anthracite stripping statistics include only the years 1936-1944; prior to 1936 the washery and dredge operations statistics were included with stripping in place of the surface works, as at present.

Employment at anthracite stripping operations has remained nearly constant during the period 1936-1944 (table 47); in 1936 employment was 4.667 workers and in 1943 it was 4.589. This indicates the extent to which the changed methods of stripping and the improved equipment have affected this work, inasmuch as in the same period the output of anthracite at stripping has increased from 6,203,000 to 9,371,000 tons. The man-hours of exposure in 1936 totaled 7,503,000, and in 1943 the exposure totaled 7,731,000 man-hours.

The number of fatal and nonfatal injuries has shown little change during the period, but the fatality rate per million tons has decreased from 1.290 in 1936 and 1.053 in 1937 to 0.443 in 1942 and 0.640 in 1943. The fatality rates based upon millions of man-hours of exposure show a similar decrease from 1.066 in 1936 to 0.776 in 1943 (table 56). These greatly lowered fatality rates (both on tonnage and on man-hours of exposure bases) constitute a notable contribution to safety by those in control of stripping operations and they indicate nicely how more and intensified mechanization methods and procedures can increase safety as well as efficiency.

TABLE 56. - Accident data for anthracite stripping1/

Year	Number of injuries		Injury rates			
			Per million tons		Per million man-hours	
	Fatal	Nonfatal	Fatal	Nonfatal	Fatal	Nonfatal
1936	8	494	1.290	79.635	1.066	65.838
1937	6	248	1.053	43.539	1.004	41.503
1938	9	174	1.766	34.149	1.908	36.893
1939	7	156	1.276	28.434	1.350	30.077
1940	5	151	.814	24.571	.819	24.735
1941	6	172	.832	23.851	.973	27.888
1942	4	135	.443	14.956	.604	20.388
1943	6	330	.640	35.216	.776	42.685

1/ The stripping statistics prior to 1936 included washery and dredge operations and hence are not considered in this table.

Some Excellent Safety Records at Anthracite Mines

Anthracite mines have been operated for long periods without fatal accidents, and some mines have not suffered a lost-time injury for considerable periods, especially from falls of various kinds, which is the principal cause of accidents at anthracite mines.

Some of the outstanding ahievements in the safe operation of anthracite mines, as submitted to the Joseph A. Holmes Safety Association, are shown below:

An anthracite mine at Scranton, Pa., operated 14 months without a fatal injury while mining 2,027,461 tons with an exposure of 5,522,428 man-hours.

A mine at Plains, Pa., employing an average of 735 men, mined 1,125,107 tons of anthracite without a fatal injury during a period of 481 working days, exposure totaling 2,800,000 man-hours.

A mine near Minersville, Pa., employing an average of 750 men, worked 2 years, 1-1/2 months without a fatality. A total of 1,147,146 tons of anthracite was mined, and exposure was 3,485,008 man-hours.

An anthracite mine at St. Clair, Pa., worked one 17-month period and one 12-month period without a lost-time accident from roof falls. In the first period exposure totaled 1,804,383 man-hours and 410,000 tons of anthracite was mines. The second accident-free period lasted 12 months, and

632,553 tons of anthracite was mined. Exposure totaled 1,286,806 man-hours. The beds were 4 to 20 feet thick and dipped 5 to 90 degrees.

A mine at Mahaney Plane, Pa., worked 19 months without a lost-time injury due to roof falls. Exposure totaled 1,005,427 man-hours and production was 329,877 tons of anthracite. The beds ranged from 1-1/2 to 25 feet in thickness, and the dip of the beds ranged from 0 to 65 degrees.

Many of the anthracite mines are gassy, and over the years there have been numerous major gas-explosion disasters, probably the largest period of immunity from major anthracite explosion disasters being the period from April 28, 1938, to September 23, 1943, or nearly 5-1/2 years. During the period April 28, 1938, to January 14, 1947, or about 8-2/3 years, there was only one major gas-explosion disaster in the anthracite region, which occurred on September 24, 1943, with 14 lives lost. During 1947, however, there were 3 major gas explosions in anthracite mines in Pennsylvania, one with 15 fatalities on January 15, one with 10 fatalities on April 10, and one on December 11, 1947, with 8 fatalities. The conditions under which much of the present-day anthracite production must be obtained, especially in the variable or steeply pitching regions, usually with multiple beds, some or all of which have been mined or remined previously, some very thin, others very thick, and frequently in very gassy strata, make it difficutl to avoid gas ignitions and explosions. The over-all record of the past decade has been relatively good as to major disasters, though the occurrence of three major disasters with 33 deaths in 1947 falls far short of being commendable.

METAL AND NONMETALLIC-MINERAL MINES

Metal and nonmetallic-mineral mines have little in common with coal mines, insofar as mining methods and conditions inside the mines are concerned, except in some regions such as Alabama; but coal and noncoal mines have many hazards in common, such as falls of rock or roof, haulage, electricity, and explosives, as well as others. Coal mines have two hazards rarely encountered in metal and nonmetallic-mineral mines, namely, methane, an explosive gas, and coal dust, which is also explosive. In isolated instances, however, both explosive gas and explosive dust are found in noncoal mines and have caused major disasters.

Most metal mines are in fairly steeply dipping deposits, and mining is conducted from several levels; generally, coal mines produce coal from only one level, though in some cases mining is conducted from two or more levels or horizons, this being especially the case in anthracite mining. Ventilation of coal mines is regulated by law in most States, and mechanical ventilation is essential because of the danger from accumulations of methane; however, numerous small coal mines have little if any ventilation except what happens to occur by natural means. Mechanical ventilation of metal mines is by no means general except in the larger mines, and some of them use mechanical ventilation only for local distribution, relying on so-called natural ventilation for the main supply of air.

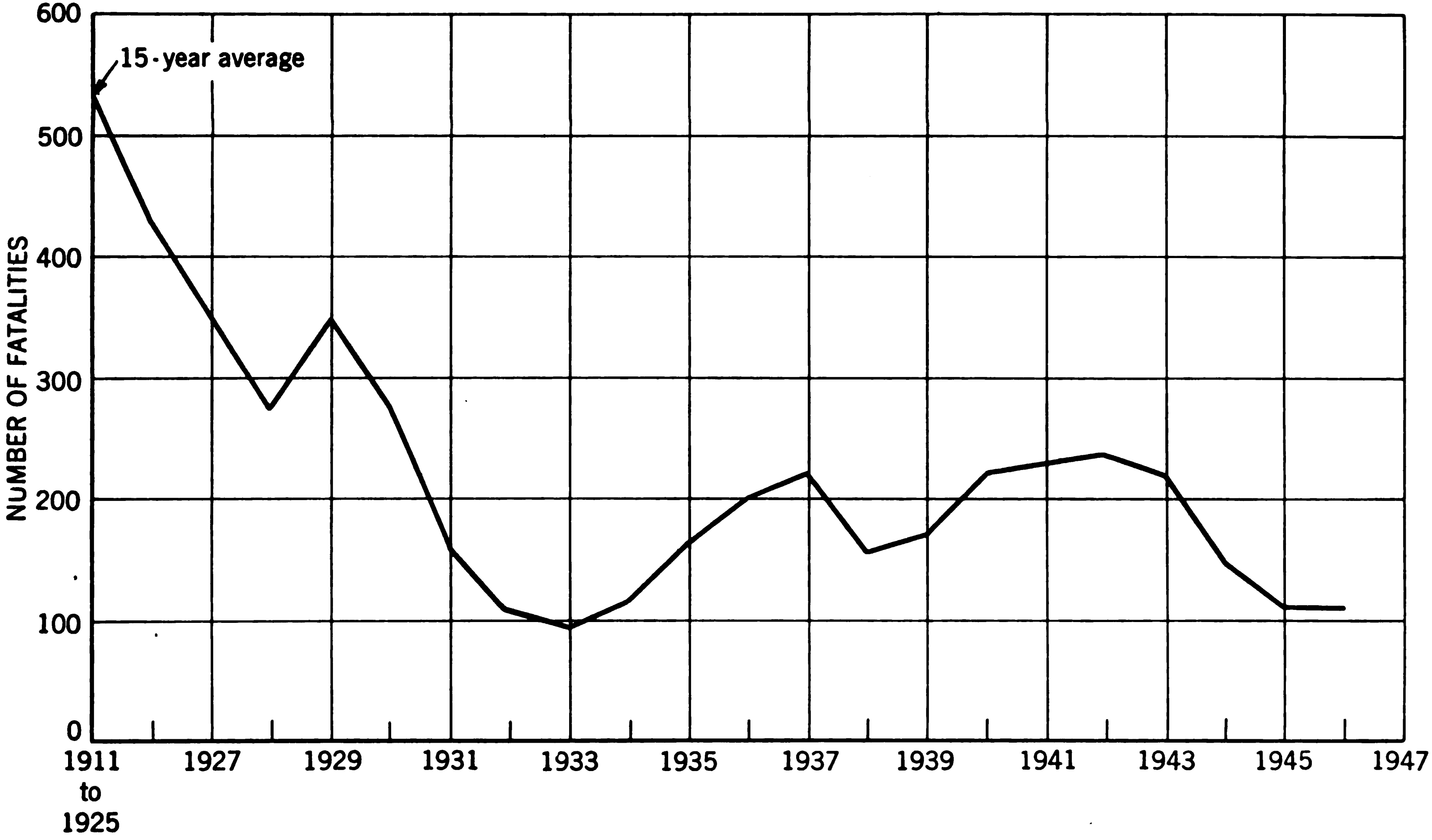

Figure 11. - Fatalities in metal and nonmetallic-mineral mines.

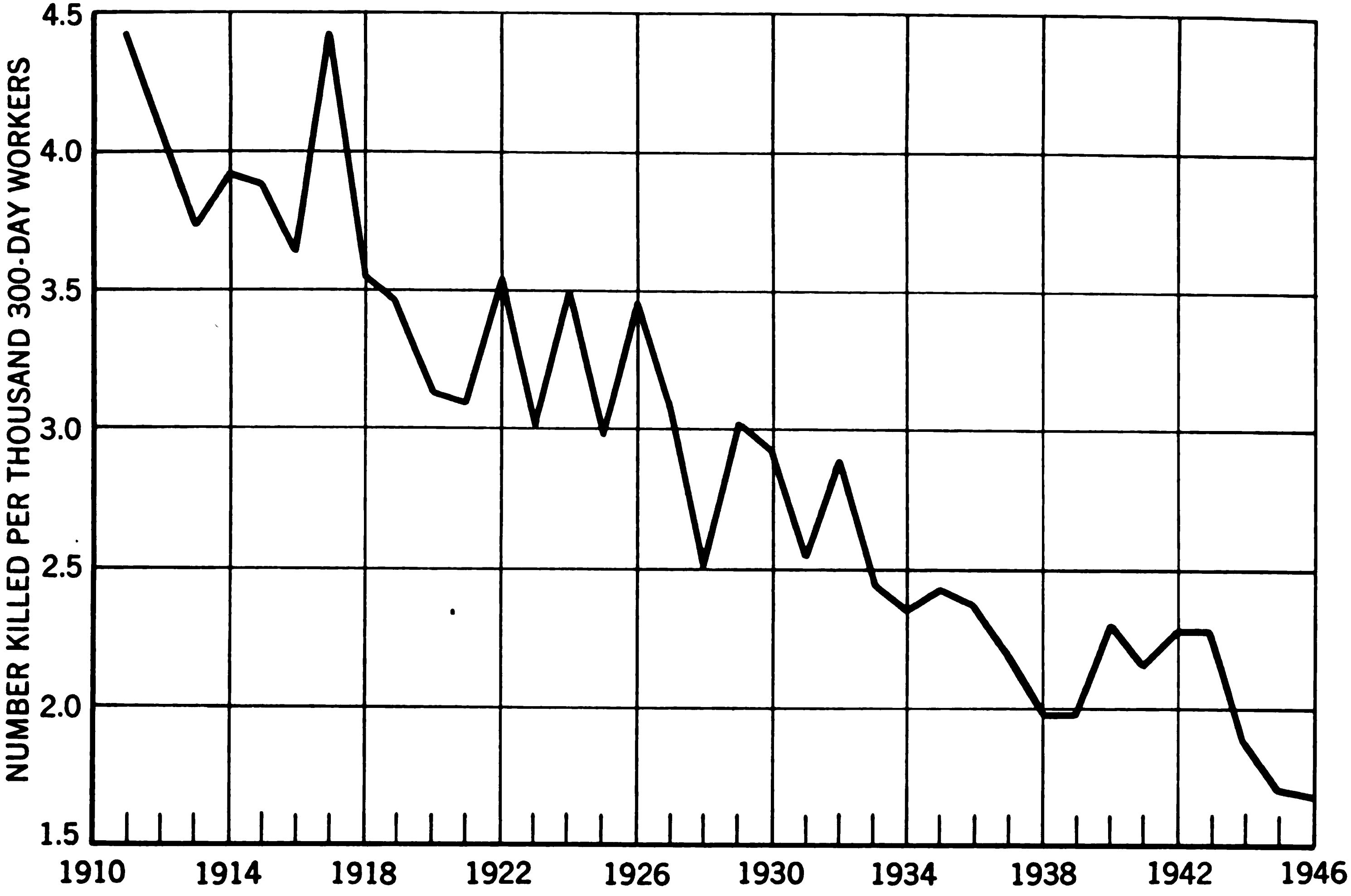

Figure 12. - Fatalities per thousand 300-day workers in metal and nonmetallic-mineral mines.

The accident statistics of the metal and nonmetallic-mineral industries are much less comprehensive than in either the bituminous-coal or anthracite industries, and as a consequence analysis of the status of safety in these mines is by no means as complete as in coal mining.

The tonnage of ore and rock produced at metal and nonmetallic-mineral mines seldom is reported except as to iron ore, gypsum, etc., in some cases, and statistics usually must be compared on the basis of employment of workers in the various branches of the industry. Man-hours were reported to the Bureau of Mines for the first time in 1931; such reporting is voluntary and is chiefly rough estimates, especially those prior to 1930.

The employment of workers, total number of shifts worked, average number of days the mines were active, number of workers killed or injured annually, and injury rates based upon thousands of 300-day workers are shown in table 57 for 1911-1945. The injury figures were by no means as completely or regularly reported prior to 1930 as they have been since that date. The number of fatalities in metal and nonmetallic mines and the number killed per thousand 300-day workers are charted in figures 11 and 12.

Table 57 indicates clearly the heavy decrease in employment in the noncoal mines of the United States from the 150,000 to 200,000 in the decade 1911-1920 to the approximately 100,000 in the decade 1936-1945. The table and figures also show great decreases in number of fatal and nonfatal accidents since 1911, when 695 persons were killed, as against the 112 of 1945, and the 26,577 nonfatal accidents in 1911 as contrasted with the 8,090 in 1945. The fatal-accident rate per 100,000 employed in noncoal mines in 1911 was 4.45 as against the 1.62 rate of 1945, and the nonfatal rate per 100,000 employed in 1911 was 170.27 against the 117.00 rate of 1945. Evidently the noncoal mines of the United States have done a good job in the reduction of the fatal-accident rate since 1911, and table 57 shows that the nonfatal rate has been heavily reduced as compared with the 1911-1920 decade.

The accident rates per million man-hours for all mines except coal mines for 1931-1945 are shown in table 58; on this basis the fatality rate has been lowered from 1.01 in 1931 to 0.67 in 1945, whereas the nonfatal-injury rate has decreased from 55.76 in 1931 to 48.63 in 1945. The nonfatal-injury rate increased for several years after 1931, and in 1937 it was 75.37 per million man-hours of employment; at least some of this increase, probably most of it, is due to the fact that data were assembled much more completely and carefully for the years immediately subsequent to 1930 than they had been previously.

The metal and nonmetallic-mineral mines of the United States are classified by the Bureau of Mines into five groups for statistical purposes, namely, (1) copper mines, (2) iron mines, (3) gold, silver, and miscellaneous mines, (4) lead-zinc mines (Mississippi Valley), and (5) nonmetallic-mineral mines. The grouping of the mines was changed in 1942, and the data since that year are not comparable with those of the period 1911-1942. The footnotes shown on tables 59 and 60 give the grouping of the mines.

TABLE 57. - Accident data for all noncoal mines in the United States, 1911-1945

Year	Average days active	Number men employed	Total shifts, in 1,000's	Number of workers		Injury rates per thousand 300-day workers	
				Killed	Injured	Killed	Injured
1911	282	165,979	46,827	695	26,577	4.45	170.27
1912	287	169,199	48,499	661	30,724	4.09	190.11
1913	288	191,276	55,078	683	32,971	3.72	179.59
1914	271	158,115	42,786	559	30,216	3.92	211.87
1915	280	152,118	42,599	553	35,295	3.89	248.56
1916	282	204,685	57,736	697	48,237	3.62	250.64
1917	287	200,579	57,626	852	46,286	4.44	240.97
1918	297	182,606	54,302	646	42,915	3.57	237.09
1919	297	145,262	40,461	468	31,506	3.47	233.60
1920	296	136,583	40,362	425	32,562	3.16	242.02
1921	238	93,929	22,353	230	18,604	3.09	249.69
1922	276	105,697	29,141	344	26,080	3.54	268.48
1923	297	123,279	36,560	367	33,563	3.01	275.41
1924	290	123,128	35,734	418	33,118	3.51	278.04
1925	293	126,713	35,172	371	35,132	2.99	283.53
1926	291	127,823	37,161	430	30,350	3.47	245.01
1927	284	119,699	34,034	352	25,133	3.10	221.54
1928	288	113,866	32,804	273	22,483	2.50	205.61
1929	292	118,735	34,618	350	23,092	3.03	200.11
1930	270	103,233	27,870	271	15,594	2.92	167.86
1931	231	80,940	18,721	158	8,709	2.53	139.56
1932	208	53,288	11,095	107	5,014	2.89	135.57
1933	204	57,016	11,642	95	5,925	2.45	152.68
1934	221	66,645	14,723	116	7,892	2.36	160.81
1935	220	92,314	20,352	164	10,206	2.42	150.44
1936	250	100,932	25,210	199	14,650	2.37	174.34
1937	252	118,429	29,857	219	18,055	2.20	181.42
1938	228	103,027	23,506	156	12,722	1.99	162.37
1939	233	111,909	26,032	173	13,710	1.99	157.99
1940	242	120,120	29,046	223	14,766	2.30	152.51
1941	255	125,290	31,954	230	15,772	2.16	148.17
1942	280	112,446	31,442	237	13,957	2.26	133.08
1943	291	100,752	29,274	220	13,025	2.25	133.48
1944	288	81,741	23,540	147	10,192	1.87	129.89
1945	289	71,841	20,744	112	8,090	1.62	117.00

TABLE 58. - Accident rates per million man-hours for all mines except coal mines, 1931-1945

Year	Average of active	Number of men	Man-hours, in 1,000's	Number of injuries		Rate per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1931	231	80,940	156,178	158	8,709	1.01	55.76
1932	208	53,288	92,038	107	5,014	1.16	54.48
1933	204	57,016	94,139	95	5,925	1.01	62.94
1934	221	66,645	116,146	116	7,892	1.00	67.95
1935	220	92,314	161,303	164	10,206	1.02	63.27
1936	250	100,932	202,359	199	14,650	.98	72.40
1937	252	118,429	239,544	219	18,055	.91	75.37
1938	228	103,027	188,170	156	12,722	.83	67.61
1939	233	111,909	206,835	173	13,710	.84	66.28
1940	242	120,120	230,728	223	14,766	.97	64.00
1941	255	125,290	253,678	230	15,772	.91	62.17
1942	280	112,446	251,187	237	13,957	.94	55.56
1943	291	100,752	234,703	220	13,025	.94	55.50
1944	288	81,741	188,929	147	10,192	.78	53.95
1945	289	71,841	166,347	112	8,090	.67	48.63

TABLE 59. - Comparison of fatality rates per thousand 300-day workers in various branches of metal and nonmetallic industries

Year	Copper	Iron[1]	Gold, silver, miscellaneous[2]	Lead and zinc[3]	Nonmetallic minerals[4]	Total
1911	5.18	4.64	4.28	4.03	2.01	4.45
1912	4.53	3.90	4.32	4.28	1.66	4.10
1913	4.08	3.29	3.83	3.90	3.02	3.72
1914	3.85	3.78	4.06	4.32	3.73	3.92
1915	3.72	2.88	4.79	5.37	2.43	3.89
1916	3.64	3.41	4.05	3.14	3.00	3.62
1917	5.88	3.54	4.03	4.09	2.48	4.44
1918	3.45	3.45	4.27	3.58	1.67	3.57
1919	3.54	3.09	4.41	4.13	1.65	3.47
1920	3.43	2.34	4.20	3.27	2.89	3.16
1921	3.70	3.04	3.29	2.58	1.98	3.09
1922	3.00	3.00	5.35	2.64	2.39	3.54
1923	3.11	2.38	3.93	2.73	2.67	3.01
1924	3.55	2.95	4.99	2.76	1.94	3.51
1925	2.94	2.54	3.83	3.32	1.71	2.99

See footnotes at end of table.

TABLE 59. - Comparison of fatality rates per thousand 300-day workers in various branches of metal and nonmetallic industries (Cont'd.)

Year	Copper	Iron 1/	Gold, silver, miscellaneous 2/	Lead and zinc 3/	Nonmetallic minerals 4/	Total
1926	3.45	4.23	3.27	3.05	2.62	3.47
1927	3.46	2.45	3.91	2.64	2.19	3.10
1928	3.03	2.16	2.60	1.62	2.13	2.50
1929	3.03	2.98	3.66	2.08	2.29	3.03
1930	2.76	2.68	4.49	1.63	.75	2.92
1931	3.01	1.91	2.88	2.56	1.63	2.53
1932	3.01	1.18	3.66	3.95	1.56	2.89
1933	2.49	1.82	3.20	.85	1.39	2.45
1934	1.96	1.59	3.33	.91	1.23	2.36
1935	2.05	2.15	2.86	2.26	1.01	2.42
1936	2.62	2.01	2.70	3.33	.45	2.37
1937	2.26	1.73	2.60	1.47	1.52	2.20
1938	1.66	1.69	2.27	3.38	.80	1.99
1939	2.17	1.55	2.08	2.88	1.37	1.99
1940	2.36	1.86	2.44	3.31	1.74	2.30
1941	2.70	2.06	2.10	1.69	1.75	2.16
1942	1.99	2.02	3.01	1.36	1.95	2.26
1943	2.77	1.65	2.22	2.56	2.19	2.25
1944	1.92	1.60	1.59	2.53	1.61	1.87
1945	1.56	1.61	1.03	2.04	1.59	1.62

1/ Data for 1911-42 exclude and for 1943-46 include manganiferrous and titaniferrous iron ores.

2/ Data for 1911-42 include and for 1943-46 exclude figures on manganiferrous and titaniferrous iron ores. Data for 1911-42 include and for 1943-46 exclude figures on lead-zinc mines outside the Mississippi Valley States.

3/ Data for 1911-42 relate only to lead-zinc mines within the Mississippi Valley States and for 1943-46 relate to all lead-zinc mines in the United States. Data for 1911-42 include and for 1943-46 exclude figures on fluorspar mines within the Mississippi Valley States.

4/ Data for 1911-42 exclude and for 1943-46 include figures on fluorspar mines within the Mississippi Valley States.

TABLE 60. - Comparison of fatality rates per million man-hours in various branches of the metal and nonmetallic-mineral industries, 1931-1946

Year	Copper	Iron[1]	Gold, silver, miscellaneous[2]	Lead and zinc[3]	Nonmetallic minerals[4]	Total
1931	1.24	0.72	1.19	1.06	0.61	1.01
1932	1.24	.44	1.52	1.63	.59	1.16
1933	1.04	.72	1.34	.35	.57	1.01
1934	.81	.66	1.42	.38	.53	1.00
1935	.85	.89	1.21	.94	.43	1.02
1936	1.09	.84	1.12	1.38	.19	.98
1937	.94	.72	1.08	.61	.63	.91
1938	.69	.70	.94	1.42	.34	.83
1939	.90	.64	.88	1.20	.58	.84
1940	.99	.77	1.03	1.38	.74	.97
1941	1.12	.86	.89	.71	.73	.91
1942	.83	.84	1.27	.57	.80	.94
1943	1.15	.69	.92	1.07	.89	.94
1944	.80	.67	.65	1.06	.66	.78
1945	.65	.67	.44	.85	.65	.67
1946[5]	.77	.56	.39	.86	.87	.69

[1] Data for 1911-42 exclude and for 1943-46 include manganiferrous and titaniferrous iron ores.

[2] Data for 1911-42 include and for 1943-46 exclude figures on manganiferrous and titaniferrous iron ores. Data for 1911-42 include and for 1943-46 exclude figures on lead-zinc mines outside the Mississippi Valley States.

[3] Data for 1911-42 relate only to lead-zinc within the Mississippi Valley States and for 1943-46 relate to all lead-zinc mines in the United States. Data for 1911-42 include and for 1943-46 exclude figures on fluorspar mines within the Mississippi Valley States.

[4] Data for 1911-42 exclude and for 1943-46 include figures on fluorspar mines within the Mississippi Valley States.

[5] Estimated.

Comparison of the fatality rates per thousand 300-day workers in the various branches or groups of the industry for 1911-1945 is given in table 59. The fatality rates per million man-hours for these groups in 1931-1946 are shown in table 60. The over-all trend is slowly downward, but with many fluctuations in the individual years.

Principal Causes of Underground Accidents

The principal causes of accidents in underground metal and nonmetallic-mineral mines are (1) falls of rock or ore from the roof (back) or wall, (2) explosives, (3) haulage, (4) falling down chutes or raises or into winzes.

In shaft mines, falling down shafts and riding the skip, cage, or bucket are also important causes of accidents (table 61). These are discussed briefly, and some suggestions are made in regard to them.

TABLE 61. - Fatal accidents at underground metal mines, classified into principal causes, 1940-45

	Number of fatal accidents					
	1940	1941	1942	1943	1944	1945
Fall of rock from roof or wall	81	74	70	76	49	49
Fall of rock or ore while loading at working face	0	2	1	0	3	0
Hand tools	0	0	0	2	0	0
Explosives	26	16	15	9	12	10
Haulage	4	11	27	28	18	12
Falling down chute or raise	21	22	18	9	9	4
Other falls of persons	0	0	2	1	1	3
Run of ore from chute or pocket	7	3	7	2	4	0
Drilling	1	1	0	0	0	0
Electricity	3	5	7	3	3	2
Machinery	2	5	3	2	2	2
Mine fires	0	2	8	0	0	0
Suffocation from natural gases	5	6	3	2	1	0
Inrush of water	0	0	0	7	1	0
Stepping on nail	0	0	0	0	0	0
Handling material other than rock or ore	0	1	2	0	0	1
Other causes	7	12	7	15	5	2
Total	157	160	170	156	108	85
Shaft:						
Falling down shaft	12	16	5	8	4	3
Objects falling down shaft	1	2	5	4	2	0
Breaking cables	0	0	0	0	0	1
Over winding	0	1	1	0	1	0
Skip, cage, or bucket	6	3	6	5	4	2
Other causes	2	1	0	5	4	3
	21	23	17	22	15	9
Total underground fatalities	178	183	187	178	123	94

Falling rock or ore from roof (back) or wall

Falls of rock or ore from roof (back) or wall is the principal cause of accidents at underground metal and nonmetallic-mineral mines; in fact, nearly one half of the underground accidents in those mines are attributed to this cause, roughly paralleling coal mining, in which more than half of the fatalities are due to falls of roof or coal. Failure to bar down loose rock or ore from overhead or from the walls, failure to test the roof, and inadequate or improperly placed timbers or excessive delay in placing timbers are largely responsible for these accidents. The use of miners picks instead of bars or bars that are too short, as well as the improper use of bars, all contribute to these accidents. This hazard is intensified in noncoal mines because usually mining is done from numerous vertical horizons, and material can fall from the roof as well as the walls and also the floor. Closer supervision of working places and better support of loose rock that cannot be taken down should help materially to reduce accidents from this source. In many cases this particular hazard is increased when the method of mining is inapplicable to the particular type of strata in which the mining is done.

Explosives

Explosives cause many accidents each year, and over a period of years explosives undoubtedly would rank second in being the cause of fatal or ultra-severe accidents underground in noncoal mining. In an explosives accident it is not unusual for all persons nearby to be killed or badly maimed; the severity of accidents from this cause is very high. Much information regarding the safe methods of use and handling of explosives has been published by the manufacturers of explosives, Bureau of Mines, and other agencies, and it is only by teaching the miners the safe methods of handling and using explosives and strict adherence to these methods that accidents from this cause can be reduced or largely eliminated. Short fusing and ignorance of the burning rate of fuse have contributed heavily to accidents from explosives, and this condition continues at this time.

Haulage

Haulage is another important cause of accidents in underground noncoal mining; in some years the number of persons killed in haulage accidents is exceeded only by those from falls of rock or ore from the roof or wall. The causes of haulage accidents include insufficient clearance between moving transportation equipment and the walls, roof, or timbers, coupling cars, riding on the top of loaded cars or between cars, and other similar conditions or actions. The haulage equipment of noncoal mines, especially the ore cars, usually are of a design that makes avoidance of accidents difficult. Adequate clearance should be provided in all haulageways in noncoal as well as in coal mines, and safe transportation practices should be taught and required. The problem is a difficult one requiring maximum cooperation of workers and management; it is analogous to the very difficult problem of trying to prevent traffic accidents on our streets and highways.

Falling Down Chutes or Raises or into Winzes

Falling down chutes or raises or into winzes is an important cause of accidents underground in noncoal mines; in the 3-year period 1940-1942 an average of 20 men were killed annually in this type of accident. Guarding the entrances to raises or chutes and the use of grizzly bars are the common methods of preventing accidents of this class. Providing and maintaining effective ladders and sollars and keeping them clear of debris helps much to reduce accidents from falls. Some mines place electric lights at each raise, winze, or chute to give the employees warning of danger. Maintenance of manways in safe condition is the joint responsibility of management and workers, and neither should shirk that duty.

Shaft Mines

In shaft mines, falling down shafts is the principal cause of shaft accidents, and riding the cage, skip, or bucket is second. The collars of all shafts and the shaft stations should be well guarded; self-closing gates or doors should be provided when feasible. Riding on skips or buckets and unauthorized riding of cages should be prohibited; riding on the rim of a bucket or skip or riding on the bale of a skip is exceedingly dangerous at most mines.

Electricity, machinery, handling materials, runs of ore from chutes or pockets, drilling and handling rock or ore while loading or working at the face are all frequent causes of accidents in underground metal and nonmetallic mines.

Although not listed as a main cause of underground accidents, defective ventilation is one of the main contributing factors in the causation of all of the above types of accidents, including those from falls, haulage, explosives, etc. In fact, adequate well-controlled ventilation is one of the most important features in the prevention of both accidents and ill health in noncoal mines, and there is no foundation for the far too prevalent idea that because noncoal mines seldom contain explosive gas they do not require careful, continuous, controlled ventilation. Controlled and efficient ventilation is more important in noncoal than coal mines, insofar as alleviating harmful health conditions is concerned, and if it were not for the occurrence of explosive gas and dust in most coal mines, the noncoal mines would have greater need of adequate ventilation, from a safety point of view, also, than would coal mines. Noncoal mines as well as coal mines are likely to be exceptionally hazardous during a mine fire unless equipped with well-installed and operated mechanical ventilation. So-called natural ventilation is inefficient at most times of the year, and during a fire it is hazardous in the extreme.

Copper Mines

Employment and accident statistics of the copper-mining industry have been compiled by the Bureau of Mines since 1911; during this period tremendous changes have taken place in the industry, new mining districts have been opened, and many of the older districts have been virtually abandoned. Mining of large low-grade ore deposits by open-cut methods has become feasible, and in 1944 open-cut mines produced 72 percent of the total copper ore mined in this country. Comparisons and conclusions relative to statistics of accidents in copper mining are very likely to be confusing and misleading if these facts are not kept in mind.

Employment in copper mines has fluctuated greatly from a high of 61,275 persons in 1917 to a low of 6,976 in 1933, when many of the mines were not operating. Accidents have been greatly reduced in maintaining and increasing the copper production in this country.

In 1911 employment was 41,693 men, the man-days of employment were 13,774,000, and there were 238 fatal and 10,342 nonfatal injuries. By comparison, in 1946 it is estimated that 13,600 workers were employed 3,739,000 man-days and 23 fatal and 1,565 nonfatal injuries occurred during the year. In 1945 there were 14,542 men employed who worked 4,435,000 man-days, and 23 fatal and 1,531 nonfatal injuries occurred (table 62). In 1911 there were 17.28 fatalities per 1,000,000 man-days, and in 1945 and 1946 there were 5.63 fatalites per 1,000,000 man-days.

TABLE 62. - Accident data at copper mines in the United States, based upon millions of man-hours

Year	Men employed	Man-days, in 1,000's	Man-hours, in 1,000's	Accidents		Rates per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1911	41,693	13,774		238	10,342		
1912	51,776	15,831		239	13,637		
1913	56,139	17,369		236	13,363		
1914	44,686	12,845		165	13,367		
1915	47,174	14,211		176	15,254		
1916	61,228	18,932		230	20,168		
1917	61,275	19,086		374	19,935		
1918	59,447	19,104		220	20,513		
1919	39,327	11,856		140	12,236		
1920	35,254	11,182		128	12,047		
1921	18,300	4,461		55	4,722		
1922	25,739	7,505		75	8,025		
1923	32,477	10,306		107	11,993		
1924	32,477	10,228		121	11,858		
1925	33,266	10,421		102	12,179		
1926	32,723	10,512		121	10,102		
1927	30,724	9,625		111	8,379		
1928	30,561	9,901		100	7,293		
1929	37,147	11,984		121	8,941		
1930	27,692	8,250		76	5,321		
1931	19,687	5,076	[1] 41,019	51	2,580	1.24	62.90
1932	9,555	2,291	18,608	23	859	1.24	46.16
1933	6,976	1,690	13,472	14	734	1.04	54.49
1934	8,084	1,841	14,727	12	669	.81	45.43
1935	10,188	2,787	22,293	19	1,466	.85	65.76
1936	14,102	4,355	34,900	38	2,819	1.09	80.77
1937	21,175	6,498	51,982	49	4,938	.94	94.99
1938	17,582	4,329	34,630	24	2,098	.69	60.58
1939	18,436	5,255	42,098	38	2,481	.90	58.93
1940	19,498	6,091	48,672	48	2,575	.99	52.91

See footnotes at end of table.

TABLE 62. - Accident data at copper mines in the United States, based upon millions of man-hours (Cont'd.)

Year	Men employed	Man-days, in 1,000's	Man-hours, in 1,000's	Accidents		Rates per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1941	21,576	6,887	55,130	62	2,961	1.12	53.71
1942	23,222	7,544	60,390	50	2,985	.83	49.43
1943	23,700	7,586	60,689	70	3,506	1.15	57.77
1944	18,826	5,936	47,496	38	2,552	.80	53.73
1945[2] ...	14,542	4,435	35,474	23	1,531	.65	43.16
1946[3] ...	13,600	3,739	29,910	23	1,565	.77	52.32

[1] Man-hours not available before 1931.
[2] Preliminary.
[3] Estimated.

In 1931, man-hour statistics were compiled by the Bureau of Mines for the first time, and since that year the accident rates per million man-hours of employment show a considerable reduction. The fatal accident rate per million man-hours in 1931 was 1.24, and the nonfatal injury rate was 62.90; in 1945 the fatal-accident rate was 0.65 and the nonfatal injury rate was 43.16. It is estimated that the fatal accident rate in 1946 was 0.77 per million man-hours of employment and the nonfatal injury rate was 52.32.

The employment and accident statistics for 1937-1944 are classified into underground mining, open-cut mining, surface, and total in table 63. The number of persons employed in open-cut mines has increased almost 50 percent since 1937.

The two principal causes of accidents in underground copper mines in 1943-1944 were (1) falls of rock or ore from the roof (back) or wall and (2) haulage. The following tabulation gives the number of persons killed or injured in these accidents and the percentage of the total underground accidents in this period.

	Cause of accidents		Total underground accidents
	Falls of rock or ore from roof or wall	Haulage	
Killed:			
1943	21	8	55
1944	13	3	28
Nonfatal injuries:			
1943	666	344	2,996
1944	595	266	2,166
Percentage of total underground accidents:			
Fatal:			
1943	38.2	14.5	
1944	46.4	10.7	
Nonfatal:			
1943	22.2	11.5	
1944	27.4	12.3	

TABLE 63. - Copper mines, employment and accident statistics, 1937-45

Year	Number of mines	Men employed				Man-hours of employment, in 1,000's			
		Underground	Open-cut	Surface	Total	Underground	Open-cut	Surface	Total
1937	145	13,078	2,895	5,202	21,175	31,473	7,895	12,614	51,982
1938	96	10,743	2,667	4,172	17,582	19,147	6,094	9,389	34,630
1939	93	10,783	3,168	4,485	18,436	23,550	7,866	10,681	42,098
1940	90	11,504	3,147	4,847	19,498	28,163	8,451	12,057	48,672
1941	100	12,776	5,110	3,690	21,576	31,649	14,382	9,100	55,130
1942	107	13,432	5,607	4,183	23,222	33,763	10,195	10,432	60,390
1943	175	14,092	5,048	4,560	23,700	35,225	14,136	11,328	60,689
1944	221	10,772	4,367	3,687	18,826	26,520	11,848	9,128	47,496

Year	Number of mines	Fatalities				Nonfatal injuries			
		Underground	Open-cut	Surface	Total	Underground	Open-cut	Surface	Total
1937	145	45	3	1	49	4,072	280	586	4,938
1938	96	20	2	2	24	1,725	149	224	2,098
1939	93	34	3	1	38	2,074	209	198	2,481
1940	90	35	8	5	48	2,154	168	253	2,575
1941	100	52	7	3	62	2,565	204	192	2,961
1942	107	41	8	1	50	2,506	275	204	2,985
1943	175	55	11	4	70	2,166	201	185	2,351
1944	221	28	8	2	38	2,996	243	267	3,506

Iron Mines

Employment and accident statistics of the iron-mining industry for the years 1911-1946 are not as readily comparable by individual years as in some other branches of the mining industry; the methods of mining have changed greatly during this time, and comparisons of annual statistics are somewhat misleading. Wide fluctuations in employment occurred, brought about by economic conditions as well as by the changing methods of mining. Employment ranged from a high of 57,230 in 1917 to a low of 11,954 in 1932.

Most of the production of iron ore in 1911 was from underground mines, but by 1944 open-cut mines produced 73.8 percent of the total iron ore mined. Many improvements were made in mining methods and mining equipment, and greater attention was given to safe practices, with the result that far fewer workers lost their lives. In 1911, 197 fatalities and 10,722 nonfatal injuries occurred in mining iron ore. Employment totaled 45,955 men, and 12,749,000 man-days were worked. It is estimated that 24,500 men were employed in 1946 for a total of 5,540,000 men-days; 25 fatalities and 1,200 nonfatal injuries occurred. In 1945 23,443 men worked 6,696,000 man-days and 36 fatalities and 1,326 nonfatal injuries occurred (table 64).

TABLE 64. - Accident data at iron mines in the United States, based upon millions of man-hours

Year	Men employed	Man-days, in 1,000's	Man-hours, in 1,000's	Accidents		Rates per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1911	45,953	12,749		197	10,722		
1912	45,746	13,035		172	10,507		
1913	51,133	15,064		165	13,473		
1914	44,807	11,746		148	8,773		
1915	39,391	10,711		103	8,337		
1916	53,488	14,869		169	11,904		
1917	57,230	16,188		191	12,278		
1918	53,665	15,563		179	9,621		
1919	47,676	13,489		139	9,098		
1920	45,990	13,575		106	9,072		
1921	30,559	6,411		65	4,507		
1922	32,241	8,286		83	4,901		
1923	38,419	11,215		89	5,616		
1924	36,629	9,852		97	4,959		
1925	34,339	9,433		80	5,013		
1926	33,158	9,144		129	4,082		
1927	33,386	8,921		73	3,409		
1928	29,145	7,787		56	2,547		
1929	28,219	8,051		80	2,404		
1930	29,410	7,723		69	2,096		
1931	21,786	4,408	1/31,121	28	774	0.72	19.78
1932	11,954	1,775	15,909	7	264	.44	16.59
1933	13,954	1,982	16,782	12	334	.72	19.90
1934	15,477	3,013	24,107	16	485	.66	20.12
1935	14,041	3,077	24,683	22	440	.89	17.83
1936	18,592	4,318	34,693	29	868	.84	25.02
1937	22,957	5,717	45,914	33	1,383	.72	30.12
1938	18,006	3,556	28,914	20	456	.70	15.99
1939	19,769	4,451	35,694	23	602	.64	16.87
1940	23,250	5,639	45,238	35	853	.77	18.86
1941	25,870	6,848	54,911	47	1,220	.86	22.22
1942	28,956	8,328	66,993	56	1,579	.84	23.57
1943	30,058	8,593	70,019	48	1,742	.69	24.88
1944	25,852	7,300	58,558	39	1,412	.67	24.11
1945	23,443	6,696	53,781	36	1,326	.67	24.66
1946 2/ ...	24,500	5,540	44,390	25	1,200	.56	27.03

1/ Man-hours not available before 1931.
2/ Preliminary.

Man-hour statistics of the iron-mining industry were first collected by the Bureau of Mines in 1931; table 64 shows the injury rates per million man-hours of employment, which is the lowest since 1932, a year of low employment and production. The nonfatal injury rates per million man-hours of employment have increased almost steadily from 15.99 in 1938 to 27.03 in 1946; the increase in injury rates probably is due to heavy production during the war years, employment of inexperienced persons, and more complete reporting of minor injuries.

Employment and accident statistics for the period 1937-1944 are shown in table 65. These statistics are classified into underground, open-cut, surface, and total.

In underground mining, falls of rock or ore from roof or wall is the principal cause of accidents. The following tabulation shows how important it is to stop accidents due to this cause:

	1943	1944
Accidents due to falls of rock or ore from roof or wall:		
Fatal	19	17
Permanent total disability	0	0
Permanent partial disability	9	15
Temporary	246	192
Total nonfatal injuries	255	207
All underground accidents:		
Fatal	32	32
Nonfatal	1,200	1,012
Percentage of total underground accidents due to fall of rock or ore from roof or wall:		
Fatal	59.4	53.1
Nonfatal	21.2	20.5

The Joseph A. Holmes Safety Association presented 261 awards to the mines of the Lake Superior region from 1927 (when the awards were first given to mining companies) to 1947 out of 326 awards presented to metal-mining companies in the United States.

Eleven hundred and ninety-eight awards were made to mining companies, associations, mines and plants, and individuals in the mineral industries throughout the United States from 1927 to 1947, and of these the Lake Superior region received 261, or approximately 22 percent.

Some of the safety records achieved by mines in the Lake Superior region equal, and a few surpass, those of far less hazardous industries.

Many of the underground mines have operated more than 12 months without a lost-time accident. In open-pit mining, outstanding records of working with no lost-time accidents ranging from 2 to nearly 12 years have been established. One company operated for over 17 years with only two lost-time accidents.

TABLE 65. - Iron mines, employment and accident statistics, 1937-45

Year	Number of mines	Men employed				Man-hours of employment, in 1,000's			
		Under-ground	Open-cut	Surface	Total	Under-ground	Open-cut	Surface	Total
1937	269	12,225	6,026	4,706	22,957	25,602	10,418	9,894	45,914
1938	184	10,729	3,311	3,966	18,006	16,575	4,921	7,019	28,515
1939	219	11,437	4,423	3,909	19,769	20,999	7,168	7,527	35,694
1940	228	12,622	5,533	5,095	23,250	25,631	9,340	10,267	45,238
1941	322	13,724	7,853	4,293	25,870	30,049	15,357	6,504	54,911
1942	327	15,635	8,466	4,855	28,956	36,319	19,247	11,427	66,993
1943	291	16,515	9,213	5,330	30,058	36,250	21,025	12,745	70,019
1944	277	12,839	8,171	4,842	25,852	29,068	18,240	11,249	58,558

Year	Number of mines	Fatal accidents				Nonfatal injuries			
		Under-ground	Open-cut	Surface	Total	Under-ground	Open-cut	Surface	Total
1937	269	26	6	1	33	1,155	128	100	1,383
1938	184	16	3	1	20	388	42	26	456
1939	219	19	3	1	23	487	82	33	602
1940	228	29	4	2	35	645	138	70	853
1941	322	34	9	4	47	931	248	41	1,220
1942	327	41	13	2	56	1,193	295	91	1,579
1943	291	33	10	5	48	1,257	376	109	1,742
1944	277	32	7	0	39	1,012	296	104	1,412

Many open pits have operated 15 or more years and several for approximately 23 years without a fatality. Underground mines also have established many outstanding records of operation with no fatalities; one operated from the time of its opening until it was abandoned, a period of 32-3/4 years, without a fatality.

The Health and Safety Division of the Bureau of Mines looks largely to the Lake Superior region for information as to safety organizations, procedures, and results as examples to not only the metal mines but also the coal mines of the United States as to what can be done in reducing the occurrence of accidents in the mining industry of the United States.

Lead-zinc Mines in the Mississippi Valley

Bureau of Mines employment and accident statistics of the lead-zinc mines in the Mississippi Valley included the fluorspar mines of Illinois and Kentucky until 1942; from 1943 to the present these mines have been excluded from Bureau of Mines statistics on fluorspar. Total employment and accident statistics for 1911-1945 are shown in table 66. The nonfatal injury rates per million man-hours of employment have decreased considerably since 1931, the first year the Bureau of Mines compiled man-hour statistics. In 1931 the nonfatal-injury rate per million man-hours of exposure was 72.81; this rate decreased to 51.40 in 1937 and then increased to 70.45 in 1944 and 65.70 in 1945. The fatality rates for the same period have fluctuated widely from a high of 1.63 in 1932 to 1.02 in 1945, with several low years, such as 0.57 in 1942 and 0.61 in 1937. Virtually all the lead-zinc ore from this area is produced from underground mines (table 67).

TABLE 66. - Accident data at lead-zinc mines in the Mississippi Valley States,1/ based upon millions of man-hours

Year	Men employed	Man-days, in 1,000's	Man-hours, in 1,000's	Accidents		Rates per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1911	12,521	3,202		43	1,488		
1912	14,332	3,783		54	1,996		
1913	12,697	3,227		42	1,436		
1914	10,935	2,779		40	1,751		
1915	12,977	3,350		60	2,661		
1916	20,615	5,443		57	4,773		
1917	20,269	4,993		68	4,544		
1918	14,004	3,517		47	3,746		
1919	12,968	3,269		45	3,185		
1920	11,638	3,299		36	3,607		
1921	6,948	1,629		14	2,062		
1922	8,900	2,500		22	3,868		
1923	10,226	2,962		27	4,894		
1924	12,734	3,696		34	5,718		
1925	12,913	3,612		40	5,636		
1926	14,479	3,831		39	3,885		
1927	12,499	3,177		28	3,152		
1928	10,334	2,598		14	2,560		
1929	11,177	2,736		19	2,173		
1930	8,524	1,837		10	1,081		
1931	6,174	1,170	2/9,464	10	689	1.06	72.81
1932	3,999	683	5,531	9	375	1.63	67.80
1933	4,633	703	5,662	2	346	.35	61.11
1934	5,069	985	7,847	3	644	.38	82.07
1935	6,728	1,192	9,592	9	660	.94	68.81
1936	6,696	1,532	12,323	17	692	1.38	56.15
1937	8,466	1,832	14,709	9	756	.61	51.40
1938	6,436	1,330	10,595	15	608	1.42	57.38
1939	7,237	1,565	12,448	15	726	1.20	58.32
1940	7,644	1,722	13,737	19	763	1.38	55.54

See footnotes at end of table.

TABLE 66. - Accident data at lead-zinc mines in the Mississippi Valley States,1/ based on millions of man-hours (Cont'd.)

Year	Men employed	Man-days, in 1,000's	Man-hours, in 1,000's	Accidents Fatal	Accidents Nonfatal	Rates per million man-hours Fatal	Rates per million man-hours Nonfatal
1941	8,634	2,131	16,917	12	992	0.71	58.64
1942	9,555	2,642	21,109	12	1,131	.57	53.68
1943	9,201	2,527	20,212	21	1,227	1.04	60.71
1944	7,856	2,239	17,941	20	1,264	1.11	70.45
1945	7,313	2,089	16,711	17	1,098	1.02	65.70

1/ Includes fluorspar mining in Illinois and Kentucky 1930-42; excludes fluorspar mining in Illinois and Kentucky 1943-45.

2/ Man-hours not available before 1931.

TABLE 67. - Lead and zinc mines (Mississippi Valley),1/ employment and accident statistics, 1937-42

Year	Number of mines	Men employed Under-ground	Men employed Open-cut	Men employed Surface	Men employed Total	Man-hours employment, in 1,000's Under-ground	Man-hours Open-cut	Man-hours Surface	Man-hours Total
1937	252	7,627	61	778	8,466	13,199	90	1,420	14,709
1938	194	5,994	51	391	6,436	9,784	86	725	10,595
1939	204	6,616	45	576	7,237	11,286	108	1,054	12,448
1940	226	6,969	67	608	7,644	12,376	170	1,190	13,737
1941	338	7,507	132	995	8,634	14,747	279	1,891	16,917
1942	430	8,377	134	1,044	9,555	18,478	300	2,331	21,109

Year	Number of mines	Fatal accidents Under-ground	Fatal accidents Open-cut	Fatal accidents Surface	Fatal accidents Total	Nonfatal injuries Under-ground	Nonfatal injuries Open-cut	Nonfatal injuries Surface	Nonfatal injuries Total
1937	252	9			9	723	5	28	756
1938	194	15			15	578	3	27	608
1939	204	15			15	660	11	55	726
1940	226	19			19	730	11	22	763
1941	338	11	1		12	930	13	49	992
1942	430	11		1	12	1,046	24	61	1,131

1/ Includes fluorspar mines in Illinois and Kentucky.

Gold, Silver, and Miscellaneous Metal Mines

The Bureau's classification of metal mines contains a group entitled "gold, silver, and miscellaneous metal mines," which includes gold mines (both lode and placer), silver mines, lead-silver and gold-silver mines, lead and zinc mines other than those of the Mississippi Valley, and mines of manganese, quicksilver, tungsten, vanadium, chromium, pyrite, and bauxite, as well as other metals. It is not feasible to show the status of safety in any one particular mineral production in this group. Table 68 shows employment and accident statistics of this group of mines for the period 1911-1945 as well as the accident rates based upon millions of man-hours since 1931, the first year the Bureau of Mines collected man-hour data.

Table 69 shows a classification of the employment, man-hour, and fatal-accident statistics into underground, open-cut, and surface. The table also shows the number of mines studied.

TABLE 68. - Accident data at gold, silver, and miscellaneous metal mines in the United States, based upon millions of man-hours

Year	Men employed	Man-days, in 1,000's	Man-hours, in 1,000's	Accidents		Rate per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1911	48,919	13,513		193	3,618		
1912	44,144	12,230		176	3,793		
1913	59,501	16,434		210	3,855		
1914	48,438	13,241		179	5,601		
1915	45,312	12,473		199	8,377		
1916	60,107	16,092		217	10,234		
1917	51,892	14,582		196	8,385		
1918	43,643	12,713		181	7,847		
1919	32,130	8,577		126	5,469		
1920	29,933	8,355		117	5,704		
1921	26,516	7,121		78	5,352		
1922	27,614	7,843		140	6,805		
1923	30,525	8,705		114	8,672		
1924	29,718	8,713		145	8,649		
1925	33,230	10,028		128	10,276		
1926	33,940	9,895		108	9,878		
1927	30,461	8,752		114	8,162		
1928	31,622	9,132		79	8,180		
1929	30,861	8,698		106	7,810		
1930	27,045	7,276		109	5,813		
1931	24,343	6,039	[1] 48,633	58	3,825	1.19	78.65
1932	21,094	5,000	40,165	61	2,988	1.52	74.39
1933	23,775	5,538	44,091	59	3,766	1.34	85.42
1934	29,781	6,937	54,278	77	5,307	1.42	97.77
1935	53,018	11,210	88,567	107	6,827	1.21	77.08
1936	51,162	12,316	98,887	111	9,227	1.12	93.31
1937	55,814	13,249	106,403	115	9,991	1.08	93.90
1938	51,477	12,039	96,602	91	8,834	.94	91.45
1939	56,837	12,565	99,314	87	9,182	.88	92.45
1940	59,948	13,179	104,093	107	9,749	1.03	93.66

[1] Man-hours not available prior to 1931.

TABLE 68. - Accident data at gold, silver, and miscellaneous metal mines in the United States, based upon millions of man-hours (Cont'd.)

Year	Men employed	Man-days, in 1,000's	Man-hours, in 1,000's	Accidents		Rate per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1941	58,122	13,168	103,495	92	9,417	0.89	90.99
1942	39,480	9,856	77,827	99	6,992	1.27	89.84
1943	24,921	6,954	55,322	56	5,058	1.01	91.43
1944	17,879	4,873	39,032	33	3,666	.85	93.92
1945	15,996	4,453	35,328	20	2,967	.57	83.98

TABLE 69. - Gold, silver, and miscellaneous metal mines, employment and accident statistics, 1937-1945

Year	Number of mines	Men employed				Man-hours employment, in 1,000's			
		Underground	Open-cut	Surface	Total	Underground	Open-cut	Surface	Total
1937	7,932	36,240	3,054	16,520	55,814	72,889	3,976	29,538	106,403
1938	6,136	31,643	3,243	16,591	51,477	63,284	3,921	29,397	96,602
1939	7,821	33,945	3,368	19,524	56,837	63,896	4,106	31,311	99,314
1940	9,947	35,968	3,414	20,566	59,948	67,048	4,475	32,570	104,093
1941	8,247	34,200	4,256	19,666	58,122	63,696	6,291	33,508	103,495
1942	4,512	23,705	3,315	12,460	39,480	49,668	5,492	22,668	77,827

Year	Number of mines	Fatal accidents				Nonfatal accidents			
		Underground	Open-cut	Surface	Total	Underground	Open-cut	Surface	Total
1937	7,932	99	1	15	115	8,420	115	1,456	9,991
1938	6,136	87	2	2	91	7,505	169	1,160	8,834
1939	7,821	74	7	6	87	7,684	160	1,338	9,182
1940	9,947	88	4	15	107	8,039	191	1,519	9,749
1941	8,247	75	6	11	92	7,642	224	1,551	9,417
1942	4,512	79	6	14	99	5,799	188	1,005	6,992

Nonmetallic-mineral Mines

The mines included in the classification "nonmetallic-mineral mines" are those that produce asbestos, asphaltum, barite, borax, emery, feldspar, fluorspar (except in Illinois and Kentucky), garnet, graphite, gypsum, lithium, magnesite, mica, mineral paint, phosphate rock, potash, quartz, salt, soapstone, sulfur, talc, and tripoli.

Employment and accident statistics for the nonmetallic-mineral mines for 1911-1945 are shown in table 70. Total employment did not fluctuate as much in this group of mines as in the groups previously considered; the high was 13,893 workers in 1911 and the low was 6,686 men in 1932. The percentage of fatalities per million man-hours of employment has increased from 0.61 in 1931 to 0.89 in 1943 and 0.65 in 1945. The nonfatal-injury rates remain virtually the same as in 1931.

TABLE 70. - Accident data at nonmetallic-mineral mines in the United States, 1911-1945

Year	Men employed	Man-days, in 1,000's	Man-hours, in 1,000's	Accidents		Rates per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1911 ...	13,893	3,588		24	407		
1912 ...	13,201	3,619		20	801		
1913 ...	11,806	2,984		30	844		
1914 ...	9,249	2,174		27	724		
1915 ...	7,624	1,854		15	666		
1916 ...	9,247	2,401		24	1,158		
1917 ...	9,913	2,777		23	1,144		
1918 ...	11,847	3,405		19	1,188		
1919 ...	13,161	3,270		18	1,518		
1920 ...	13,768	3,951		38	2,132		
1921 ...	11,606	2,730		18	1,961		
1922 ...	11,113	2,007		24	2,481		
1923 ...	11,632	3,372		30	2,388		
1924 ...	11,570	3,246		21	1,934		
1925 ...	12,965	3,678		21	2,028		
1926 ...	13,523	3,779		33	2,403		
1927 ...	12,629	3,559		26	2,031		
1928 ...	12,204	3,386		24	1,903		
1929 ...	11,331	3,149		24	1,764		
1930 ...	10,562	2,784		7	1,283		
1931 ...	8,949	2,029	1/17,941	11	841	0.61	46.88
1932 ...	6,686	1,347	11,825	7	528	.59	44.65
1933 ...	7,678	1,729	14,134	8	745	.57	52.71
1934 ...	8,234	1,947	15,187	8	787	.53	51.82
1935 ...	8,339	2,068	16,168	7	813	.43	50.28
1936 ...	10,380	2,689	21,556	4	1,044	.19	48.43
1937 ...	10,017	2,561	20,536	13	987	.63	48.06
1938 ...	9,526	2,251	27,827	6	726	.34	40.72
1939 ...	9,630	2,196	17,281	10	719	.58	41.61
1940 ...	9,780	2,416	18,988	14	826	.74	43.50
1941 ...	11,088	2,920	23,225	17	1,182	.73	50.89
1942 ...	11,233	3,072	24,867	20	1,270	.80	51.07
1943 ...	12,713	3,426	27,999	25	1,471	.89	52.54
1944 ...	11,261	3,173	25,760	17	1,283	.66	49.81
1945 ...	10,371	3,016	24,613	16	1,145	.65	46.52

1/ Excludes fluorspar mining in Illinois and Kentucky, 1943-45; includes fuller's earth mining 1930-45; excludes fuller's earth mining 1943-45.

The classification of the employment and accident statistics into underground mining, open-cut mining, and surface is shown in table 71.

TABLE 71. - Nonmetallic-mineral mines, employment and accident statistics, 1937-43

Year	Number of mines	Men employed				Man-hours employment, in 1,000's			
		Underground	Open-cut	Surface	Total	Underground	Open-cut	Surface	Total
1937	445	3,101	3,583	3,333	10,017	5,854	6,816	7,866	20,536
1938	623	2,685	3,981	2,860	9,526	4,887	6,372	6,568	17,827
1939	786	2,635	4,077	2,918	9,630	4,577	6,030	6,674	17,281
1940	639	3,017	4,102	2,661	9,780	5,865	6,740	6,383	18,988
1941	613	3,537	5,471	2,080	11,088	7,446	10,405	5,374	23,225
1942	691	3,669	5,429	2,135	11,233	8,033	11,190	5,645	24,867

Year	Number of mines	Fatal accidents				Nonfatal accidents			
		Underground	Open-cut	Surface	Total	Underground	Open-cut	Surface	Total
1937	445	8	2	3	13	385	336	266	987
1938	623	1	4	1	6	242	306	178	726
1939	786	5	3	2	10	279	229	211	719
1940	639	7	7	0	14	359	276	191	826
1941	613	11	6	0	17	518	482	182	1,185
1942	691	15	4	1	20	564	493	213	1,270

Relative Hazards of Various Mining Methods

The selection of the mining method to be used in opening a new mine depends largely on the physical characteristics of the deposit; in many instances, however, the method selected is the one used elsewhere in the same region where similar conditions exist. Many mines use one method of mining at the start of operation, but subsequently another method is substituted or the original method is modified. It is obvious that no one method of mining can be applied to all types of mineral deposits, and generally the method adopted is modified in time to conform to conditions peculiar to the individual mine.

When selecting a mining method, safety as well as efficiency should be considered as aside from the humanitarian aspects, the cost of accidents is becoming increasingly an important item at all mines. The safeness of any mine, irrespective of the mining method used, is dependent largely on the human element and whether precautions are taken against known hazards and against unusual hazards disclosed by operating experience. However, the method of mining may have a vital influence in accident occurrence.

Employment and accident statistics for 1938-1942 are classified by mining methods in table 72. The 5-year period shown in the table is too short to permit forming of definite conclusions as to the relative safeness of a mining method, but the available data indicate what has been occurring. Shrinkage stoping appears to be the most hazardous method of noncoal mining; this method is used largely in steeply dipping deposits in gold, silver, lead and zinc mines of the Rocky Mountain area. The safest mining method in the period considered in table 72 is top slicing, which is used principally in mining iron ore, though it has also been used in copper and other kinds of mines. The fatality rate per million man-hours in top slicing is shown in the table to range from 0.50 to 0.82, and the nonfatal-injury rates range from 20.36 to 31.05. These rates compare favorably with those in shrinkage stoping in the same period, with a fatality rate ranging from 2.09 to 1.49 and nonfatality rate ranging from 112.81 to 134.52.

TABLE 72. - Accidents classified by mining methods, 1938-1942

Mining method	Number of mines	Men employed	Man-hours employment, in 1,000's	Accidents		Rates per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
1. Open stope, including room-and-pillar and sublevel stoping:							
1938	153	16,279	30,732	42	2,698	1.37	87.79
1939	136	16,081	31,433	38	2,228	1.10	76.46
1940	153	18,081	37,880	35	2,490	.92	65.73
1941	163	17,039	37,828	40	2,480	1.06	65.66
1942	152	10,852	25,330	26	1,774	1.03	70.04
2. Shrinkage:							
1938	42	3,414	8,035	12	1,081	1.49	134.53
1939	35	3,310	7,907	14	892	1.77	112.81
1940	48	4,504	10,708	19	1,237	1.77	115.52
1941	49	4,261	10,031	21	1,165	2.09	116.14
1942	36	2,617	5,924	11	860	1.86	145.16
3. Cut-and-fill:							
1938	38	5,423	12,081	19	1,300	1.57	107.61
1939	35	5,587	12,563	19	1,401	1.51	111.52
1940	31	5,034	11,398	11	1,384	.97	121.43
1941	32	4,191	9,825	12	1,246	1.22	126.82
1942	32	4,880	12,022	18	1,149	1.50	95.85
4. Square-set:							
1938	40	5,758	13,226	12	1,603	.91	121.20
1939	30	5,637	12,379	10	1,521	.81	122.87
1940	53	12,101	27,784	42	2,685	1.51	96.64
1941	61	13,877	32,384	50	3,180	1.54	98.20
1942	51	7,248	17,142	21	1,699	1.23	99.12
5. Block caving:							
1938	5	1,514	3,674	9	351	2.45	95.53
1939	6	1,954	5,068	9	587	1.78	115.82
1940	10	2,392	6,035	5	710	.83	117.65
1941	8	3,051	8,387	8	1,073	.95	127.94
1942	10	3,199	8,743	15	1,003	1.72	114.72

TABLE 72. - Accidents classified by mining methods, 1938-1942 (Cont'd.)

Mining method	Number of mines	Men employed	Man-hours employment, in 1,000's	Accidents		Rates per million man-hours	
				Fatal	Nonfatal	Fatal	Nonfatal
6. Sublevel caving:							
1938	14	2,043	3,535	5	103	1.41	29.14
1939	15	2,479	4,754	4	118	.84	24.82
1940	14	2,445	5,026	2	120	.40	23.87
1941	18	2,794	6,170	9	207	1.46	33.55
1942	19	2,880	6,511	9	182	1.38	27.95
7. Top slicing:							
1938	20	2,795	4,372	3	89	.69	20.36
1939	20	3,393	5,946	3	144	.50	24.22
1940	21	3,096	6,274	4	159	.64	25.34
1941	24	3,588	7,792	6	208	.77	26.69
1942	22	3,733	8,504	7	264	.82	31.05

Outstanding Safety Records at Metal and Nonmetallic-mineral Mines

Many metal and nonmetallic-mineral mines have established safety records that only a few years ago would have been considered impossible of attainment. Each year mining companies are invited to submit their safety records to the Joseph A. Holmes Safety Association. Some of these records are given below:

Iron-ore Mines

An underground iron-ore mine in Michigan employing 196 men worked 11-3/4 years without a fatal accident. The man-hours of exposure totaled 4,523,447, and the mine produced 2,892,217 tons of ore.

An underground iron ore mine in Michigan employing 104 men worked 15-1/4 years, with 3,474,716 man-hours of exposure, without a fatality.

An underground iron-ore mine in Minnesota worked 8-1/2 years and had 3,040,900 man-hours of exposure without a fatal accident. The mine produced 2,161,028 tons of ore in this period.

A mining company worked nine underground iron-ore mines in one district in Michigan and employed an average of 502 men for 7 years with 5,854,047 man-hours of exposure while producing 3,201,516 tons of ore without a fatality.

Molybdenum Mine

An underground molybdenum mine in Colorado produced 7,777,978 tons of ore in 1-1/4 years without a fatal accident.

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Copper Mines

An underground copper mine in Arizona produced 13,287,517 tons of ore in 2-1/2 years with an average employment of 602 men and 4,173,272 man-hours of exposure without a fatal accident.

An underground copper mine in Tennessee produced 2,218,558 tons of ore in 14 years without a fatality.

Lead-zinc Mine

An underground lead-zinc mine in Utah employed an average of 323 men for 4-1/2 years, with 2,670,759 man-hours of exposure, without a fatal accident.

Gold Mine

An underground gold mine in California employed an average of 244 men for 7-1/2 years, with 4,027,648 man-hours of exposure, without a fatal accident.

Open-cut Mines

An open-cut copper mine in Arizona employing an average of 550 men, with 5,828,736 man-hours of exposure in 4 years and 4 months, produced 55,035,380 tons of material without a fatal accident.

An open-cut copper mine in Utah employing 1,400 men worked 11,000,000 man-hours in 3 years while producing 75,000,000 tons of material without a fatality.

An open-pit iron-ore mine in Minnesota produced 27,114,130 tons of material in 23 years 3 months with 4,337,597 man-hours of exposure without a fatal accident.

A mining company in Minnesota operated its open-pit iron-ore mines in one district for 2 years 9-1/2 months with an average of 1,183 employees and an exposure of 6,540,641 man-hours without a fatal accident while producing 34,254,803 tons of material.

Open-cut Mines Operated Without Lost-time Accidents

An open-cut iron-ore mine in Minnesota worked 2 years 7 months without a lost-time accident while producing 19,928,509 tons of material (ore and waste). An average of 275 men worked 1,814,996 man-hours during this period.

An open-pit iron ore mine in Minnesota produced 10,647,933 tons of material in 3 years 8 months with an average of 105 men working 1,404,711 man-hours without a lost-time accident.

These records show clearly that with concerted effort on the part of employees and officials and strict adherence to recognized safe practices mining can be done without the relatively large loss of life characteristic of it in the past. Open-pit mining in which millions of tons of material is handled without lost-time accidents is a far cry from the experience record of this type of mining of 20 or more years ago and clearly indicates what can be done when company officials and employees are safety minded and work harmoniously toward a common goal.

QUARRYING

Statistics of the quarrying industry usually cover both quarries and related plants, such as cement plants; and in many instances employment in related plants exceeds that in the quarries. In this paper statistics of employment and accidents at the related plants are given, as well as for the entire industry, but the statistics of the quarries themselves are emphasized.

The physical aspects of quarries vary widely; some are open pits in fairly flat strata, others are side-hill quarries with low or high faces and with strata at various inclinations, and still others are underground workings. The statistics do not differentiate between the side-hill quarries and open-pit quarries, but separate statistics for the underground quarries are available.

Table 73 shows the employment, man-hours, accidents, and the injury rates per million man-hours for 1911-1945. The injury rates previous to 1916 are believed not to be complete; the man-hours shown for 1911-1923 are computed.

Employment in all types of quarries has decreased almost 50 percent since 1911, the first year for which these statistics are available. The decrease is due probably to increased mechanization and to improvement in equipment and procedure. In 1911 a total of 110,954 men were employed in quarrying and related plants; in 1945 only 58,180 men were so employed.

The industry as a whole has reduced both the number of accidents and the accident rate per million man-hours of employment. In the 10-year period 1911-1920 an average of 164 men were killed and 9,299 men were injured annually, whereas in the 10-year period 1936-1945 an average of 76 men were killed and 5,446 men were injured each year, a decrease of 53.5 percent in the number of fatal injuries. The fatal-injury rates per million man-hours for 1931-1945 have declined little; in 1931 the rate was 0.46, in 1936 it was 0.62, and in 1941, 0.44. The fatal-injury rate in 1945 was 0.42.

Employment and accident statistics for the 10-year period 1936-1945, classified by open quarries, underground quarries, total quarries, and outside works, are shown in table 74. The fatality and injury rates per million man-hours of employment for the total quarries and the outside works also are shown in this table. The injury rates per million man-hours of employment have shown a definite downward trend since 1941, when the rate was 61.33, and in 1945 was 47.81. The fatality rates in the same period have shown an erratic course rather than a definite trend, ranging from 1.25 in 1942 to 0.76 in 1945 and 1.05 in 1944.

The severity rate of quarry accidents for 1936-1945 is shown in table 75.

TABLE 73. - Employment and accident statistics for the quarrying and related industries, 1911-1945

Year	Number men employed	Man-hours employment in 1,000's 1/	Accidents		Rate per million man-hours	
			Fatal	Nonfatal	Fatal	Nonfatal 2/
1911	110,954	237,043	188	5,390	0.79	22.74
1912	113,105	263,494	213	6,552	.81	24.87
1913	106,278	244,691	183	7,739	.75	31.63
1914	87,936	191,470	180	7,836	.94	40.93
1915	100,740	231,512	148	9,671	.64	41.77
1916	90,797	214,692	173	13,427	.81	62.54
1917	82,290	200,841	131	13,242	.65	65.93
1918	68,332	166,472	125	8,719	.75	52.38
1919	75,505	179,135	123	9,199	.69	51.35
1920	86,488	216,465	178	11,217	.82	51.82
1921	77,185	168,363	120	10,465	.71	62.16
1922	79,081	193,362	132	11,839	.68	61.23
1923	92,455	239,109	143	14,990	.60	62.69
1924	94,242	236,983	138	14,777	.58	62.35
1925	91,872	233,222	149	14,165	.64	60.74
1926	91,146	230,464	154	13,201	.67	57.28
1927	91,517	229,806	135	13,459	.59	58.57
1928	89,667	224,953	119	10,568	.53	46.98
1929	85,561	211,766	126	9,810	.59	46.32
1930	80,633	186,502	105	7,417	.56	39.77
1931	69,200	133,750	61	5,427	.46	40.58
1932	56,866	93,710	32	3,574	.34	38.14
1933	61,927	87,888	59	3,637	.67	41.38
1934	64,331	95,259	60	3,924	.63	41.19
1935	73,005	110,033	51	4,152	.46	37.73
1936	80,022	147,064	91	5,717	.62	38.87
1937	84,094	158,299	77	6,348	.49	40.10
1938	77,497	133,766	82	5,027	.61	37.58
1939	79,449	143,847	48	5,204	.33	36.18
1940	79,509	147,244	72	5,188	.49	35.23
1941	86,123	173,165	76	6,870	.44	39.67
1942	84,270	180,836	112	6,349	.62	35.11
1943	69,877	155,280	80	5,199	.52	33.48
1944	58,476	129,302	73	4,437	.56	34.32
1945	58,180	127,168	53	4,121	.42	32.41
1946					.31	

1/ Man-hours for 1911-1923 are computed.
2/ Injury rates previous to 1916 are believed not to be representative.

TABLE 74. - Injury rates per million man-hours at quarries and related industries, 1936-1945

	Open Quarry								
	Men	Accidents		Men	Accidents		Men	Accidents	
Year	employed	Fatal	Nonfatal	employed	Fatal	Nonfatal	employed	Fatal	Nonfatal
1936..	32,951	45	3,237	2,686	5	297	35,637	53	3,534
1937..	33,909	38	3,585	2,970	9	345	36,879	47	3,930
1938..	30,740	58	2,929	2,604	2	199	33,344	60	3,128
1939..	31,489	29	3,145	2,611	2	230	34,100	31	3,375
1940..	30,664	49	2,902	2,714	3	242	33,378	52	3,144
1941..	32,904	48	3,768	3,042	6	302	35,946	54	4,070
1942..	30,838	81	3,190	3,210	3	357	34,048	84	3,547
1943..	23,968	43	2,467	2,830	5	308	26,798	48	2,775
1944..	19,570	44	2,005	2,370	4	243	21,940	48	2,248
1945..	19,307	28	1,830	2,246	5	250	21,553	33	2,080

	Outside works			Fatality rate per million man-hours			Injury rate per million man-hours		
	Men	Accidents			Outside			Outside	
Year	employed	Fatal	Nonfatal	Quarry	works	Total	Quarry	works	Total
1936	44,385	38	2,183	0.89	0.44	0.62	59.14	25.00	38.87
1937	47,215	30	2,418	.74	.32	.49	62.10	25.45	40.10
1938	44,153	22	1,899	1.15	.27	.61	59.97	23.27	37.58
1939	45,349	17	1,829	.56	.19	.33	60.45	20.78	36.18
1940	46,131	20	2,044	.94	.22	.49	56.61	22.29	35.23
1941	50,177	22	2,800	.81	.21	.44	61.33	26.22	39.67
1942	50,222	28	2,802	1.25	.25	.62	52.82	24.65	35.11
1943	43,079	32	2,424	.86	.32	.52	49.70	24.37	33.48
1944	36,536	35	2,189	1.05	.30	.56	49.00	26.24	34.32
1945	36,627	20	2,041	.76	.24	.42	47.81	24.40	32.41

TABLE 75. - All quarries, severity of accidents, 1936-1945

		Injured				
	Killed	Permanent total	Permanent partial	Temporary	Total nonfatal	Grand total
Open quarry:						
1936	48	5	96	3,136	3,237	3,285
1937	38	2	92	3,491	3,585	3,623
1938	58	2	77	2,850	2,929	2,987
1939	29	7	74	3,064	3,145	3,174
1940	49	2	88	2,812	2,902	2,951
1941	48	7	101	3,660	3,768	3,816
1942	81	10	66	3,114	3,190	3,271
1943	43	3	56	2,408	2,467	2,510
1944	44	2	49	1,954	2,005	2,049
1945	28	7	27	1,796	1,830	1,858

TABLE 75. - All quarries, severity of accidents, 1936-1945 (Cont'd.)

		Injured				
	Killed	Permanent total	Permanent partial	Temporary	Total nonfatal	Grand total
Underground quarry:						
1936	5	1	4	286	291	296
1937	9	0	4	338	342	351
1938	2	0	9	185	194	196
1939	2	1	6	222	229	231
1940	3	0	12	230	242	245
1941	6	0	11	290	301	307
1942	3	0	7	346	353	356
1943	4	0	11	289	300	304
1944	4	0	9	230	239	243
1945	4		3	241	244	248
Shaft or slope:						
1936	0	0	0	6	6	6
1937	0	0	0	3	3	3
1938	0	0	0	5	5	5
1939	0	0	0	1	1	1
1940	0	0	0	0	0	0
1941	0	0	0	1	1	1
1942	0	0	0	4	4	4
1943	1	0	0	8	8	9
1944	0	0	1	3	4	4
1945	1		1	5	6	7
Outside works:						
1936	38	2	71	2,110	2,183	2,221
1937	30	2	77	2,339	2,418	2,448
1938	22	3	67	1,829	1,899	1,921
1939	17	0	61	1,768	1,829	1,846
1940	20	0	70	1,974	2,044	2,064
1941	22	5	71	2,724	2,800	2,822
1942	28	0	67	2,735	2,802	2,830
1943	32	1	69	2,354	2,424	2,456
1944	25	1	53	2,135	2,189	2,214
1945	20	1	50	1,990	2,041	2,061

TABLE 75. - All quarries, severity of accidents, 1936-1945 (Cont'd.)

	Killed	Injured				
		Permanent total	Permanent partial	Temporary	Total nonfatal	Grand total
Grand total:						
1936	91	8	171	5,538	5,717	5,808
1937	77	4	173	6,171	6,348	6,425
1938	82	5	153	4,869	5,027	5,109
1939	48	8	141	5,055	5,204	5,252
1940	72	2	170	5,016	5,188	5,260
1941	76	12	183	6,675	6,870	6,946
1942	112	10	140	6,199	6,349	6,461
1943	80	4	136	5,059	5,199	5,279
1944	73	3	112	4,322	4,437	4,510
1945	53	8	81	4,032	4,121	4,174

The causes of fatal and nonfatal injuries in open quarries, underground quarries and shafts, and slopes at underground quarries are shown in tables 76, 77, and 78, respectively.

The Bureau of Mines uses eight principal divisions of the quarrying industry for statistical purposes, namely:

1. Cement rock
2. Granite
3. Limestone
4. Limestone, chief product lime
5. Marble
6. Sandstone
7. Slate
8. Traprock

Employment and accident statistics for the 6-year period 1940-1945 for each of the principal divisions are shown in table 79. The quarries have decreased in number from 2,104 in 1940 to 1,691 in 1945, and the total number of employees at quarries has dropped in the same period from 33,378 to 21,553. In the same period, the total number of employees in the quarries and related works has decreased from 79,509 in 1940 to 58,180 in 1945. The number of fatal accidents each year in the quarries has ranged from 84 in 1942 to 33 in 1945, whereas the total fatalities for the industry ranged from 112 in 1942 to 53 in 1945. The fatality rates per million man-hours at the quarries have not shown a definite trend; the rate in 1940 was 0.94, in 1942 it was 1.25, and in 1944 it was 1.05. The rate in 1945 was 0.76. The nonfatal-injury rate per million man-hours of employment has changed little during the period.

TABLE 76. - Open quarries, causes of fatal and nonfatal injuries, 1936-45

Cause of injury	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Fatalities:										
Falls or slides of rock	13	12	18	8	20	8	9	16	10	7
Handling materials	1	1	3	2	1	2	1	1	3	1
Hand tools	0	0	0	0	0	0	0	-	-	-
Explosives	14	7	9	4	5	10	35	3	6	2
Haulage	6	4	6	2	9	6	11	8	7	3
Falls of persons	2	3	6	4	5	8	5	4	5	3
Falling objects.	1	3	1	0	0	2	4	-	2	1
Flying objects..	0	2	0	0	0	1	0	1	1	1
Electricity	3	1	4	2	1	0	5	2	3	-
Drilling and channeling	1	0	0	0	0	1	0	1	-	1
Machinery	4	0	7	3	5	5	6	5	5	7
Stepping on nail	0	0	0	0	0	0	0	-	-	-
Boiler and air tank explosions	0	0	0	0	1	0	0	-	1	-
Burns	0	0	1	2	1	1	2	-	-	1
Other causes ...	3	5	3	2	1	4	3	2	1	1
Total	48	38	58	29	49	48	81	43	44	28
Nonfatal injuries:										
Falls or slides of rock	293	273	242	288	269	341	312	210	171	130
Handling materials	1,008	1,071	858	885	914	1,128	805	599	434	382
Hand tools	205	223	190	185	182	210	207	134	126	109
Explosives	58	52	51	54	53	87	73	46	48	55
Haulage	219	272	179	215	173	214	222	210	184	147
Falls of persons	257	352	301	319	284	363	358	281	226	226
Falling objects.	137	153	99	117	86	124	91	97	83	69
Flying objects..	374	409	367	405	320	440	381	241	170	153
Electricity	13	11	15	14	12	23	21	15	11	8
Drilling and channeling	155	167	165	127	125	220	193	141	124	127
Machinery	246	278	190	234	216	322	256	217	200	176
Stepping on nail	12	30	16	15	21	15	7	5	2	4
Boiler and air tank explosions	2	0	1	4	2	1	0	1	1	1
Burns	34	44	58	32	36	48	36	40	31	53
Other causes ...	224	250	197	251	209	232	228	230	194	190
Total	3,237	3,598	2,929	3,145	2,902	3,768	3,190	2,467	2,005	1,830

TABLE 77. - Underground quarries, causes of fatal and nonfatal injuries, 1936-42

Cause of injury	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Fatalities:										
Fall of rock from roof or wall	2	2	0	1	2	5	1	2	2	
Handling rock at face or chute	0	0	0	0	0	0	0	1		
Hand tools	0	0	0	0	0	0				
Explosives	0	5	1	0	1	0	0			
Haulage	2	2	1	0	0	0	1	1	1	4
Falling down chute raise winze or stope	0	0	0	0	0	0		1	1	
Run of rock from chute	0	0	0	1	0	0	0			
Drilling	0	0	0	0	0	0	0			
Electricity	0	0	0	0	0	0	0			
Machinery, other than locomotives and drills	0	0	0	0	0	0	0			
Mine fires	0	0	0	0	0	0	0			
Suffocation from gas	0	0	0	0	0	0	0			
Inrush of water	0	0	0	0	0	0	0			
Stepping on nail	0	0	0	0	0	0	0			
Handling materials other than rock	0	0	0	0	0	0	0			
Other causes	1	0	0	0	0	1	1			
Total	5	9	2	2	3	6	3	5	4	4
Nonfatal injuries:										
Fall of rock from roof or wall	32	55	32	19	28	42	38	39	39	34
Handling rock at face or chute	59	101	61	54	77	92	84	68	56	55
Hand tools	14	14	8	30	17	22	28	14	8	15
Explosives	6	10	4	7	3	3	1	5		3
Haulage	35	30	16	19	23	16	43	29	14	12
Falling down chute, raise, winze or stope	2	8	0	4	6	3	11	12	5	3
Run of rock from chute	20	5	8	11	3	6	1	6	8	7
Drilling	25	29	17	32	29	34	60	45	46	56
Electricity	0	0	0	0	0	1	1	1	1	3
Machinery, other than locomotive or drill	8	15	7	7	5	15	20	10	11	10
Mine fires	0	0	0	0	0	1	0			1
Suffocation from gas	0	1	0	0	0	3	2			
Inrush of water	0	0	0	0	0	0	0			
Stepping on nail	0	1	6	1	1	1	1	1		
Handling material other than rock	34	22	9	13	14	27	17	18	13	10
Other causes	56	51	26	32	36	35	46	52	38	35
Total	291	342	194	229	242	301	353	300	239	244

TABLE 78. - Shafts or slopes at underground quarries, causes of fatal and nonfatal injuries, 1936-45

Cause of injury	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Fatalities:										
Falling down shaft	0	0	0	0	0	0	0	1	0	0
Objects falling down shaft	0	0	0	0	0	0	0	0	0	1
Breaking cables	0	0	0	0	0	0	0	0	0	0
Overwinding	0	0	0	0	0	0	0	0	0	0
Cage, skip, or bucket...	0	0	0	0	0	0	0	0	0	0
Other causes	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	1	0	1
Nonfatal injuries:										
Falling down shaft	1	0	0	0	0	0	1	2	2	0
Object falling down shaft	1	0	1	1	0	1	0	0	1	1
Breaking cables	0	0	2	0	0	0	0	0	0	0
Overwinding	0	0	0	0	0	0	0	0	0	0
Cage, skip, or bucket ..	0	2	0	0	0	0	2	2	0	2
Other causes	4	1	2	0	0	0	1	4	1	3
Total	6	3	5	1	0	1	4	8	4	6

TABLE 79. - Employment and accident data classified by kind of quarry, 1940-45

	Cement rock	Granite	Lime-stone	Limestone, chief product lime	Marble	Sand-stone	Slate	Trap rock	Total
Number of quarries:1/									
1940	181	260	957	238	61	175	87	145	2,104
1941	182	266	1,074	230	56	175	86	134	2,203
1942	178	235	1,119	221	44	151	71	140	2,159
1943	171	196	939	203	28	115	46	115	1,813
1944	165	183	863	178	31	108	41	123	1,692
1945	164	173	849	172	43	136	41	113	1,691
Men employed at quarry:									
1940	3,768	3,985	15,320	3,994	1,156	2,150	1,109	1,896	33,378
1941	4,082	4,478	16,931	4,392	827	2,236	1,123	1,877	35,946
1942	4,173	3,670	16,891	4,081	633	1,905	888	1,807	34,048
1943	3,564	2,502	13,692	3,469	343	1,599	396	1,233	26,798
1944	2,772	2,148	11,099	2,825	382	1,266	311	1,137	21,940
1945	2,780	2,103	10,593	2,639	474	1,465	291	1,208	21,553

See footnote at end of table.

TABLE 79. - Employment and accident data classified by kind of quarry, 1940-45 (Cont'd.)

	Cement rock	Granite	Lime-stone	Limestone, chief product lime	Marble	Sand-stone	Slate	Trap rock	Total
Total men employed:									
1940	26,695	7,162	23,251	10,332	3,240	3,078	2,800	2,951	79,509
1941	28,859	7,830	26,395	11,292	2,693	3,180	2,845	3,029	86,123
1942	30,235	6,307	26,629	10,656	2,205	2,840	2,284	3,114	84,270
1943	25,811	4,646	21,742	10,186	1,540	2,441	1,255	2,256	69,877
1944	20,605	4,278	18,182	8,653	1,450	2,243	1,071	1,994	58,476
1945	20,858	4,067	17,704	8,162	1,748	2,574	988	2,079	58,180
Man-hours employment at quarry, in 1,000's:									
1940	6,967	6,510	23,719	8,338	1,980	3,288	1,930	2,805	55,538
1941	8,393	8,304	29,343	9,471	1,440	4,018	2,134	3,259	66,363
1942	8,943	7,080	32,157	9,576	1,071	3,523	1,620	3,182	67,152
1943	7,415	5,028	27,856	8,592	741	3,069	811	2,319	55,832
1944	5,585	4,312	22,622	7,170	786	2,541	679	2,181	45,877
1945	5,531	4,254	20,444	6,380	955	2,933	627	2,383	43,507
Nonfatal injuries at quarry:									
1940	99	379	1,475	550	115	189	141	196	3,144
1941	132	502	1,907	785	79	276	138	251	4,070
1942	159	365	1,731	662	49	225	116	240	3,547
1943	157	273	1,332	580	28	206	37	162	2,775
1944	114	248	1,018	416	27	180	40	145	2,248
1945	89	236	917	414	37	189	50	148	2,080
Total nonfatal injuries:									
1940	521	543	1,953	1,056	242	249	355	269	5,188
1941	705	719	2,622	1,551	240	349	323	361	6,870
1942	787	531	2,530	1,342	171	320	334	334	6,349
1943	773	403	1,936	1,284	137	278	134	254	5,199
1944	637	385	1,596	1,050	102	293	146	228	4,437
1945	600	396	1,381	961	164	309	115	195	4,121
Nonfatal injury rates per million man-hours at quarry:									
1940	14.21	58.22	62.19	65.96	58.09	57.48	73.05	69.87	56.61
1941	15.73	60.45	64.99	82.88	54.85	68.69	64.66	77.01	61.33
1942	17.78	51.56	53.83	69.13	45.76	63.87	71.60	75.41	52.82
1943	21.17	54.30	47.82	67.51	37.77	67.12	45.61	69.85	49.70
1944	20.41	57.51	45.00	66.38	34.34	70.85	58.90	66.48	49.00
1945	16.09	55.48	44.85	64.89	38.76	64.44	79.68	62.12	47.81

TABLE 79. - Employment and accident data classified by kind of quarry, 1940-45 (Cont'd.)

	Cement rock	Granite	Lime-stone	Limestone, chief product lime	Marble	Sand-stone	Slate	Trap rock	Total
Nonfatal injury rate per million man-hours, total:									
1940	9.44	44.26	52.54	47.07	40.32	50.80	70.83	62.94	35.23
1941	10.93	49.40	55.96	61.30	46.33	59.76	57.21	68.31	39.67
1942	11.07	42.39	48.98	52.35	38.55	59.49	74.44	59.43	35.11
1943	12.99	41.94	42.96	50.33	37.04	56.82	50.07	58.98	33.48
1944	13.92	43.00	42.21	47.00	30.68	60.54	61.17	58.58	34.32
1945	12.48	45.97	39.25	48.99	43.24	56.73	49.97	49.15	32.41
Number fatalities at quarry:									
1940	5	10	19	8	1	5	1	3	52
1941	5	6	23	14	0	2	1	3	54
1942	2/32	13	22	8	1	1	2	5	84
1943	7	4	25	6		2		4	48
1944	3	6	24	8		2	3	2	48
1945	2	7	16	3	2	3			33
Total fatalities:									
1940	15	12	21	12	3	5	1	3	72
1941	14	8	30	17	0	2	1	4	76
1942	46	14	30	12	2	1	2	5	112
1943	21	5	31	15		4		4	80
1944	15	6	29	14	1	2	3	3	73
1945	9	7	24	8	2	3			53
Fatality rate per million man-hours at quarry:									
1940	0.72	1.54	0.80	0.96	0.51	1.52	0.52	1.07	0.94
1941	.60	.72	.78	1.48	.00	.50	.47	.92	.81
1942	3.58	1.84	.68	.84	.93	.28	1.23	1.57	1.25
1943	.94	.80	.90	.70		.65		1.72	.86
1944	.54	1.39	1.06	1.12		.79	4.42	.92	1.05
1945	.36	1.65	.78	.47	2.10	1.02			.76

See footnote at end of table.

TABLE 79. - Employment and accident data classified by kind of quarry, 1940-45 (Cont'd.)

	Cement rock	Granite	Lime-stone	Limestone, chief, product lime	Marble	Sand-stone	Slate	Trap rock	Total
Total fatality rate per million man-hours:									
1940	0.27	0.98	0.56	0.53	0.50	1.02	0.20	0.70	0.49
1941	.22	.55	.64	.67	.00	.34	.18	.76	.44
1942	.65	1.12	.58	.47	.45	.19	.45	.89	.62
1943	.35	.52	.69	.59		.82		.93	.52
1944	.33	.67	.77	.63	.30	.41	1.26	.77	.56
1945	.19	.81	.68	.41	.53	.55			.42

1/ Includes a small number of mills or other plants not operated in connection with quarries.

2/ Includes loss of 28 lives at Sandts Eddy quarry near Easton, Pa.

The accident-frequency rates for all injuries, both fatal and nonfatal, for each of the eight branches of the quarrying industry are shown in table 80. The same table also shows the accident-frequency rates for open quarries, underground quarries, shafts and slopes in underground quarries, and outside works for 1940-1944; only the rates available for each industry as a whole are for 1945.

Cement Rock

The cement industry is the largest branch of quarrying, in point of employment, but most of the employees work in the plants and surface works. During 1940-1945, only approximately 13.5 percent of the employment in the cement industry was in the quarries. The limestone industry, the next largest branch, employed approximately 60 percent of its total workers in the quarries.

The cement industry has established by far the lowest accident rate per million man-hours of employment of any of the eight branches of quarrying (table 79) during 1940-1945. The fatal-accident rate per million man-hours in 1945 was 0.19, and the nonfatal-injury rate was 12.48; these rates compare very favorably with those for the entire quarrying industry for 1945, which were 0.42 for fatal and 32.41 for nonfatal injuries.

Various cement plants have worked long periods without a lost-time accident; one plant, including the quarry, worked 5,678 days without an accident, another 4,664 days, and still another 3,359 days. The Portland Cement Association has a very active safety program, and the progress made by the companies of the organization in safe working of its quarries and plants clearly indicates what can be done.

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TABLE 80. - Accident-frequency rates per million man-hours, 1940-45 (includes fatal and nonfatal accidents)[1]

	1940	1941	1942	1943	1944	1945
Quarries (open):						
Cement rock	12.99	16.26	22.24	23.90	22.15	
Granite	59.67	61.23	53.15	55.16	58.95	
Limestone	65.67	68.11	56.57	49.30	47.94	
Limestone, chief product lime	67.27	85.18	66.05	66.82	65.70	
Marble	53.57	55.75	42.13	28.37	38.64	
Sandstone	58.88	70.15	63.72	67.83	72.21	
Slate	73.32	66.34	71.06	46.18	49.61	
Trap rock	71.28	77.34	76.98	71.58	67.40	
Quarries (underground):						
Cement rock	25.10	16.69	15.47	9.00	12.70	
Granite	82.02	41.17	123.52	41.17	49.21	
Limestone	39.87	45.84	38.67	43.26	34.78	
Limestone, chief product lime	64.45	79.93	88.29	72.36	73.64	
Marble	76.67	45.88	75.88	93.45	29.70	
Sandstone	62.27	23.93	75.18	66.52	41.37	
Slate	76.67	53.70	82.99	38.20	121.02	
Trap rock	47.96	125.98	-	-	-	
Shaft or slope:						
Cement rock	-	-	-	-	-	
Granite	-	-	-	-	-	
Limestone	-	.32	.78	1.41	.30	
Limestone, chief product lime	-	-	.61	1.87	1.46	
Marble	-	-	-	-	9.90	
Sandstone	-	-	-	-	-	
Slate	-	-	-	5.46	-	
Trap rock	-	-	-	-	-	
Total underground quarry:						
Cement rock	25.10	16.69	15.47	9.00	12.70	
Granite	82.02	41.17	123.52	41.17	49.21	
Limestone	39.87	46.16	39.44	44.67	35.08	
Limestone, chief product lime	64.45	79.93	88.90	74.24	75.10	
Marble	76.67	45.88	75.88	93.45	39.60	
Sandstone	62.27	23.93	75.18	66.52	41.37	
Slate	76.67	53.70	82.99	43.65	121.02	
Trap rock	47.96	125.98	-	-	-	
Outside works:						
Cement rock	8.96	10.37	10.33	12.09	13.32	
Granite	28.83	35.05	30.66	28.59	29.52	
Limestone	35.69	41.24	41.40	35.45	38.38	
Limestone, chief product lime	36.17	48.58	42.59	42.14	38.23	
Marble	32.07	43.05	36.55	36.85	31.92	
Sandstone	37.19	40.06	51.19	40.59	46.26	
Slate	69.44	52.69	76.04	52.01	61.57	
Trap rock	49.70	54.81	38.57	46.29	49.09	

See footnote at end of table.

TABLE 80. - Accident-frequency rates per million man-hours, 1940-45 (includes fatal and nonfatal accidents)1/ (Cont'd.)

	1940	1941	1942	1943	1944	1945
Grand total:						
Cement rock	9.71	11.15	11.72	13.34	14.25	12.67
Granite	45.24	49.95	43.51	42.46	43.67	46.78
Limestone	53.10	56.60	49.56	43.65	42.98	39.94
Limestone, chief product lime	47.60	61.97	52.82	50.92	47.62	49.40
Marble	40.82	46.33	39.00	37.04	33.47	43.77
Sandstone	51.82	60.10	59.68	57.64	58.95	57.28
Slate	71.03	57.39	74.88	50.07	60.34	49.97
Trap rock	63.64	69.07	60.32	59.91	59.35	47.15

1/ Breakdown of data for 1945 not yet available.

A major disaster occurred at a cement-company quarry in 1942, when a premature explosion killed 28 quarry workers who were loading explosives into well-drill holes for a primary blast. The fatal-accident rate per million man-hours in 1942 was 3.58, as compared with 0.60 in 1941 and 0.94 in 1943.

Limestone

Limestone quarrying is the second largest branch of the quarry industry, with respect to employment, and the largest in number of operating quarries. In 1942 there were 1,149 quarries, and in 1945 the number had decreased to 849. The total employment in the industry in 1942 was 26,629, but in 1945 employment had decreased to 17,704. Quarries employed 15,320 men in 1940, and only 10,593 in 1945.

The quarries and related plants in this branch include all limestone-producing quarries except those whose product is used for cement and lime.

Many of the operations have side-hill quarries with very high working faces and highly inclined strata. Slides of rock or overburden are a frequent cause of accidents; however, handling materials, flying objects, falls of persons, and haulage also are important causes.

In the 3-year period 1943-1945, limestone quarries had approximately 50 percent of the fatal accidents that occurred in all the quarries of the various branches and nearly 40 percent of the fatal accidents that occurred in quarries and related plants. The fatality rate per million man-hours of employment in quarries has remained virtually the same through 1940-1945; the rate was 0.78 per million man-hours in 1945 and 0.80 in 1940. A high of 1.06 occurred in 1944 and a low of 0.68 in 1942.

Nonfatal injury rates per million man-hours in the limestone quarries have shown a substantial reduction; the nonfatal-injury rate in 1940 was 62.19, and the rate decreased to 44.85 in 1945, a reduction of 27.9 percent.

Limestone (Chief Product Lime)

Quarries producing limestone for the manufacture of lime are placed in a separate group by the Bureau of Mines for statistical purposes; the group is much smaller than the main limestone group, but the plants and related works are more extensive than the usual limestone-quarry surface plant. The quarry employees number only approximately 35 percent of the total employees of the industry; this compares with the cement industry, which has an average of 13.5 percent of the total employees working in the quarries and 60 percent in the limestone industry.

The number of quarries producing limestone for the manufacture of lime has decreased each year since 1940; the total number of quarries operating was 238 in 1940 and 172 in 1945.

Employment in quarries was 38.7 percent of the total employment in 1940 and 32.4 percent of this branch of the industry in 1945. The number of employees decreased from 3,994 in 1940 to 2,639 in 1945; the total employment decreased from 10,332 to 8,162 in the same period.

The frequency of accidents of the industry, fatal and nonfatal ranged from 47.60 in 1940, to 61.97 in 1941, and 47.62 in 1945. The frequency of quarry accidents in the same period remained nearly constant; the frequency was 67.27 in 1940 and 65.70 in 1945, with a high of 85.18 in 1941.

The fatality rates per million man-hours in 1940-1945 for the entire industry have fluctuated from a high of 0.67 in 1941 to a low of 0.41 in 1945; the nonfatal-injury rates in the same period ranged from 47.07 in 1940 to 48.99 in 1945. The quarry fatality rates per million man-hours followed the pattern of the industry as a whole; the fatality rate was 0.80 in 1940 and 0.78 in 1945.

Granite

The granite industry had 260 operating quarries in 1940 and 266 in 1941, but in 1945 the number of operating quarries had decreased to 173. The employment in quarries and related works in 1940 was 7,162 men, but by 1945 employment had fallen to 4,067, the lowest recorded in this industry by the Bureau of Mines since information was first collected in 1911.

Quarry employment dropped from 3,985 in 1940 to 2,103 in 1945, or 47.8 percent. The fatality rates per million man-hours at the quarry were unusually high for the quarrying industry, ranging from 1.54 in 1940 to 1.84 in 1942 and 1.65 in 1945. The fatality rates for the entire industry ranged 0.98 in 1940, to 1.12 in 1942, and 0.81 in 1945. The fatality rate per million man-hours for the industry has increased during the last three years from 0.52 in 1943, to 0.67 in 1944, and 0.81 in 1945.

The nonfatal injury rates in 1940-1945 remained nearly constant in both quarries and total for the industry. The rate for quarries in 1940 was 58.22 in 1940 and 55.48 in 1945. The rate for the total industry was 44.26 in 1940 and 45.97 in 1945. The rate for quarries alone was 58.22 in 1940 and 55.48 in 1945 (table 79).

Marble

The marble industry is not comparable with most of the other divisions of the quarrying industry, inasmuch as the major part of the quarry product is dimension stone and the quarrying methods are very different from those employed in the limestone and cement rock quarries.

The number of marble quarries in operation has decreased from 61 in 1940 to 43 in 1945, whereas employment inside the quarries has decreased from 1,156 to 474 in the same period, a reduction of 59 percent. The total employment at the quarry and surface works decreased from 3,240 in 1940 to 1,748 in 1945, a reduction of 46 percent (table 79).

In the period 1940-1945 the quarries has four fatal accidents out of a total of eight for the entire industry. Two fatalities occurred in 1945, causing the rate per million man-hours to be 2.10. The nonfatal injuries occurring in the quarries in the same period ranged from 115 in 1940 to 27 in 1944 and 37 in 1945. The nonfatal-injury rates per million man-hours in the same years were 58.09 in 1940, 34.34 in 1944, and 38.76 in 1945.

Both the fatal- and nonfatal-injury rates per million man-hours of employment at the quarry and surface works have shown little change in recent years; the fatal-accident rate per million man-hours in 1940 was 40.32, and in 1945 it was 43.24.

Sandstone

Sandstone is used for various purposes, including dimension stone and in the manufacture of glass; it is obtained from both open quarries and underground workings.

The number of operating quarries has decreased from 175 in 1940 to 136 in 1945, and employment inside the quarries has been reduced from 2,150 in 1940 to 1,465 in 1945. The lowest number of quarries operating was 108 in 1944, with employment of 1,266.

Total employment ranged from 3,078 workers in 1940 to 2,243 in 1944 and 2,574 in 1945 (table 79).

The fatality rate per million man-hours of employment has fluctuated greatly, from 1.52 in 1940 to 0.28 in 1942 and 1.02 in 1945; the fatality rate for the industry ranged from 1.02 in 1940 to 0.19 in 1942 and 0.55 in 1945.

The number of nonfatal injuries in sandstone quarries ranged from a high of 276 in 1941 to a low of 180 in 1944 and 189 in 1945, but the rates per million man-hours of employment have ranged from 57.48 in 1940 to 70.85 in 1944 and 64.44 in 1945. The nonfatal-injury rates for the entire industry have shown the same lack of definite trend; in 1944 the rate was 60.54 and in 1945 it was 56.73.

Slate

The number of slate quarries has decreased from 87 in 1940 to 41 in 1945, and employment has dropped from 1,109 in 1940 to 291 in 1945, a reduction of 73.8 percent. Employment in quarries and related plants dropped from 2,800 in 1940 to 988 in 1945, or 64.8 percent.

The small number of workers employed in the slate industry causes the accident statistics to be overemphasized when compared with the larger division of the quarrying industry. Three men were killed in slate quarries in 1944, and the rate per million man-hours of employment was 4.42 and the fatality rate for the entire industry was 1.26. These rates compare with a quarry rate of 0.52 in 1940 and a total fatality rate for the quarry and related works of 0.20.

The nonfatal-injury rates per million man-hours of employment have not shown a definite trend. Rates at the quarry decreased from 73.05 in 1940 to 45.61 in 1943 and increased to 79.68 in 1945. Rates for the entire industry are the lowest for the period 1940-1945; in 1945, when the rate was 49.97, the high was 74.44 in 1942.

Trap Rock

The number of trap-rock quarries has decreased from 145 in 1940 to 113 in 1945; employees inside the quarry have decreased from 1,896 in 1940 to 1,137 in 1944 and 1,208 in 1945. Total employment in quarries and related plants in 1940 was 2,951 and 2,079 in 1945; the greatest employment was in 1942, when 3,114 workers were reported.

The fatal-accident rates per million man-hours of employment in quarries has not shown a definite trend; in 1940 the rate was 1.07, and in 1943 it was 1.72. There were no fatal accidents in the quarries in 1945. The fatality rate for the industry ranged from 0.70 in 1940 to 0.77 in 1944; there were no fatal accidents in 1945 (table 79).

The nonfatal-injury rates per million man-hours of employment have decreased each year since 1941, when the rate was 77.01, and in 1945 it was 62.12. The nonfatal-injury rate for the industry ranged from 68.31 in 1941 to 47.15 in 1945, with a decrease each year.

The limestone industry, whose chief product is lime, has shown little progress in reducing the accident frequency. The frequency rate for the entire industry was 47.60 in 1940, 47.62 in 1944, and 49.40 in 1945.

The sandstone open quarries had a higher accident-frequency rate in 1944 than in 1940. The rate per million man-hours of employment was 58.88 in 1940 and 72.21 in 1944. The frequency rate for the entire industry was 51.82 in 1940 and 57.28 in 1945; the high was 60.10 in 1941.

The accident-frequency rates per million man-hours of employment in underground quarries, compared to open quarries, is shown in table 81 for 1935-1945.

It is of interest to note that the underground quarries attained a lower accident-frequency rate than open quarries each year during the period except 1945.

Accident-frequency Rates by Kind of Product

A comparison of the accident-frequency rates per million man-hours for the eight principal branches of the quarrying industry is shown in table 80; both fatal and nonfatal accidents are included in the frequency rates. The accident statistics are divided into open quarry, underground quarry, shaft or slope, total underground quarry, and outside works for the years 1940-1944; only the over-all rates are available for 1945.

The cement-rock open-quarry accident-frequency rate per million man-hours increased from 12.99 in 1940 to 22.15 in 1944; the high was 23.90 in 1943. The underground cement-rock quarries, however, lowered the accident-frequency rate from 25.10 in 1940 to 12.70 in 1944 and 9.00 in 1943. The frequency rates for the outside works increased from 9.71 in 1940 to 14.25 in 1944 and then dropped to 12.67 in 1945. These statistics indicate that for some reason the cement industry safety program is not as effective as heretofore, and every effort should be made to again attain the low accident-frequency rates previously achieved. The rates for 1944 and 1945 are lower than for other branches of the quarrying industry, but the relatively recent increases in the rates should be a cause of major concern to the cement industry.

The open quarries of the limestone industry have made considerable progress in reducing the accident-frequency rates per million man-hours; the rate was 65.57 in 1940 and 47.94 in 1944. The frequency rate for the limestone industry was 53.10 in 1940 and 39.94 in 1945.

Underground Quarries

Quarrying is characteristically a surface operation, but under certain conditions it is conducted underground. In 1935 there were 82 underground quarries in the United States, and in 1945 the underground operations had increased to 104 situated in 22 States. Pennsylvania and Missouri have the largest number of underground quarries and the largest number of men employed in this work.

Quarrying is conducted underground when the overburden of an open quarry becomes too heavy to be removed economically or when it is essential that the quarry product be delivered to the plant without excessive moisture, or when weather conditions interfere with open quarry operations and retard production. The method usually employed in quarrying underground resembles the room-and-pillar method employed in many coal mines; the overlying strata are supported on pillars, which sometimes are in definite lines and at other times are staggered. The rock is loaded mechanically into cars or trucks and transported to the surface. Electric locomotives or Diesel- or gasoline-powered trucks are used for haulage. Ventilation is provided by the numerous openings to the surface and by blower fans. In a few instances, the underground quarries have been developed so as to provide adequate mechanical ventilation by fans placed on the surface or at the foot of a shaft.

Underground quarries have slightly better accident records per million man-hours of employment than open quarries, notwithstanding that they are in reality mines and subject to many of the hazards of underground mines (table 81).

The principal causes of fatal accidents in underground quarries are (1) falls of rock, roof, or wall, (2) explosives, and (3) haulage. The principal causes of nonfatal accidents in the period 1936-1942 are (1) falls of rock or roof, (2) handling rock while loading at the working face or from a chute, (3) haulage, and (4) drilling.

Some operators of underground quarries claim the method to be more flexible than open quarries, permits selective mining and insures a more uniform product to the plant, and reduces absenteeism because of inclement weather. The mechanical equipment for this type of quarrying has improved, and it is probable that the number of these operations will increase.

TABLE 81. - Accident-frequency rates for underground quarries, 1935-1945 (underground and shaft operations only)

Year	Number of underground quarries	Underground quarries				Open quarries
		Number of employed	Injuries		Frequency rates per million man-hours	Frequency rate per million man-hours
			Fatal	Nonfatal		
1935	82	2,494	1	197	56.62	62.521
1936	93	2,686	5	297	58.34	60.186
1937	93	2,970	9	345	61.27	63.003
1938	102	2,604	2	199	49.14	62.142
1939	107	2,611	2	230	48.43	62.182
1940	108	2,714	3	242	46.31	58.792
1941	110	3,042	6	302	48.60	63.573
1942	111	3,210	3	357	49.98	54.562
1943	108	2,830	5	308	48.31	50.857
1944	105	2,370	4	243	43.43	50.983
1945	104	2,246	5	250	50.00	48.376

Relation of Size of Quarry to Frequency of Accidents

Accident statistics of the quarry industry, when classified according to the number of employees working inside the quarry, are shown in table 82. These quarries are classified into 10 employment groups ranging from "1 or 2 men" in the lowest and "400 and over" in the highest.

It is noteworthy that approximately 25 percent of the quarries employ 1 to 4 men and about 50 percent of the quarries employ less than 10 workers per quarry. The number of quarries employing 50 or more men per quarry has decreased from 118 in 1940 to 55 in 1945; this is significant in considering the accident statistics of the industry since a quarry of this size had the lowest accident frequency in the period 1940-1945.

TABLE 82. - Accident-frequency data classified by number of workers inside quarry, 1940-44

	Number of men employed in quarry										
	1-4	5-9	10-24	25-49	50-99	100-149	150-199	200-299	300-399	400 or more	Total
Number of quarries operating:											
1940	514	501	628	251	89	19	4	3	2	1	2,012
1941	545	517	616	298	104	21	4	5	1	1	2,112
1942	562	529	573	283	96	19	5	3	1	1	2,072
1943	504	463	490	195	65	16	1	2	2	1	1,739
1944	489	432	471	161	35	16	1	3			1,608
Men employed:											
1940	1,339	3,347	9,814	8,365	5,752	2,163	691	705	676	526	33,378
1941	1,455	3,469	9,386	9,811	6,767	2,300	685	1,188	345	540	35,946
1942	1,536	3,487	8,866	9,186	6,310	2,247	833	730	353	500	34,048
1943	1,378	3,123	7,608	6,766	4,202	2,001	184	488	638	410	26,798
1944	1,320	2,909	7,098	5,556	2,224	1,919	184	730			21,940
Man-hours employment, in 1,000's:											
1940	1,611	4,936	15,834	14,532	10,487	3,456	1,523	1,372	1,159	625	55,538
1941	1,941	5,484	16,864	19,265	13,648	4,311	1,476	2,223	755	396	66,363
1942	2,027	5,626	16,580	19,728	13,602	5,180	1,409	1,738	789	473	67,152
1943	1,984	5,280	15,222	14,913	9,741	4,957	474	1,140	1,014	1,107	55,832
1944	2,094	5,130	14,492	12,189	5,155	4,865	221	1,731			

TABLE 82. - Accident-frequency data classified by number of workers inside quarry, 1940-44 (Cont'd.)

	Number of men employed in quarry										
	1-4	5-9	10-24	25-49	50-99	100-149	150-199	200-299	30C-399	400 or more	Total
Fatal accidents:											
1940	4	8	16	14	6	2	1	1	0	0	52
1941	2	13	12	14	9	2	0	2	0	0	54
1942	2	4	18	1/46	10	4	0	0	0	0	84
1943	3	5	14	12	5	6		1		2	48
1944	2	8	23	5	6	4					48
Nonfatal accidents:											
1940	102	380	1,160	791	472	176	43	15	3	2	3,144
1941	144	437	1,465	1,093	697	182	23	24	5	0	4,070
1942	132	434	1,087	910	779	131	50	17	6	1	3,547
1943	140	372	940	689	411	173	5	10	12	23	2,775
1944	123	360	801	531	252	169		12			2,248
Killed and injured per million man-hours:											
1940	65.79	78.60	74.27	55.39	45.58	51.50	28.89	11.66	2.59	3.20	57.55
1941	75.02	82.05	87.58	57.46	51.73	42.69	15.58	11.69	6.63		62.14
1942	66.12	77.85	66.65	48.46	58.01	26.06	35.49	9.78	7.61	2.12	54.07
1943	72.07	71.40	62.67	47.01	42.71	36.11	10.55	9.65	11.84	22.58	50.56
1944	59.71	71.73	56.86	43.97	50.05	35.56		6.93			50.05

1/ Dynamite explosion killed 28 men at Sandts Eddy quarry near Easton, Pa.

Quarries employing 5 to 9 men had the highest frequency of accidents in the industry, ranging from 78.60 in 1940 to 71.73 in 1945; accident frequency for the entire industry was 57.55 in 1940 and 50.05 in 1945.

The relative safety of quarries should not be gaged entirely by the size of the operation, but the statistics shown in table 83 definitely indicate that the larger quarries are safer than the smaller ones. It is probable that this can be explained by better supervision, better equipment, and probably better job training given workers in the larger quarries. Essentially the same situation was found in the analysis of frequency of accidents in bituminous-coal and lignite mines.

TABLE 83. - Employment and accident data in the drilling branch of the petroleum industry

Year	Number of workers	Number of workers		Injury rates	
		Per fatality	Per disabling injury	Frequency	Severity
1934	4,084	1,021	8	69.04	6.56
1935	6,779	678	9	55.79	8.71
1936	8,888	683	9	56.74	7.59
1937	8,685	668	9	51.70	6.75
1938	8,616	1,436	10	49.51	4.44
1939	8,136	813	11	45.92	6.62
1940	8,478	1,695	13	40.03	4.35
1941	8,277	637	11	43.70	6.96
1942	5,762	2,881	10	46.28	2.84
1943	5,221	870	8	53.99	5.06
1944	6,772	616	7	65.84	6.94
1945	7,428	371	5	74.73	9.51

PETROLEUM INDUSTRY

Accident statistics of the petroleum industry have been assembled and published by the American Petroleum Institute for many years; the Bureau of Mines started to compile the accident statistics of this industry only relatively recently, hence most of the discussion of the accident record of the petroleum industry is based upon information published by the American Petroleum Institute rather than the Bureau of Mines.

The ramifications of the activities of the petroleum industry are diversified, starting with the exploration work of the geologist and geophysical surveyor "or by straight wild catting" in the search for new oil structures, drilling of the wells, production and refining of the oil, transportation of it by pipelines, rail, and steamer, and marketing, both wholesale and retail. Obviously, the hazards encountered by workers in the various branches differ, and comparisons of the accident rates of the various branches are difficult to make on any basis that is basically fair or comparable.

The geophysical exploration work includes geological studies that are made by oil geologists, assisted in more recent years by geophysical surveys. Surveys employing geophysical methods require the use of explosives, and relatively large amounts of certain types of explosives are used in this work each year. As in mining, the use of explosives brings definite hazards to those who use them, and as a consequence accidents from explosives occur relatively frequently in making geophysical surveys.

Drilling of wells involves the use of heavy equipment and tools, and this branch of the petroleum industry is the most hazardous as shown by the yearly statistics. The frequency rates for the drilling branch decreased from 69.04 in 1934 to 40.03 in 1940, but since that year they have increased to 65.84 in 1944 and 74.73 in 1945 (table 83).

The severity rate has been irregular, ranging from a high of 9.51 in 1945 to a low of 2.84 in 1942. The severity rate in 1945 was the highest since 1934.

Production

The production branch of the petroleum industry achieved a substantial decrease in the severity rate during the period 1933 to 1945, inclusive. The severity rate in 1933 was 4.35, and it decreased to 2.07 in 1944 and 1.28 in 1945. During the same period the accident-frequency rate decreased from a high of 25.74 in 1934 to 18.91 in 1944 and 18.68 in 1945. The frequency rate was 14.87 n 1940 and 14.89 in 1939 (table 84).

TABLE 84. - Employment and accident data in the production branch of the petroleum industry

Year	Number of workers	Number of workers: Per fatality	Number of workers: Per disabling injury	Injury rates: Frequency	Injury rates: Severity
1927 1/	14,474	1,033	6	59.59	3.62
1933	54,660	1,139	22	24.15	4.35
1934	50,256	1,795	21	25.74	3.32
1935	52,527	3,089	22	23.93	2.39
1936	54,115	1,746	21	24.90	3.26
1937	57,342	1,850	21	23.33	2.79
1938	56,701	1,955	27	17.93	2.31
1939	53,515	2,548	33	14.89	1.95
1940	50,197	2,282	34	14.87	2.28
1941	47,933	2,996	32	15.41	1.80
1942	47,953	2,524	32	15.28	1.85
1943	46,221	2,889	25	18.22	1.66
1944	46,713	1,946	22	18.91	2.07
1945	51,360	5,136	23	18.68	1.28

1/ Includes drilling.

Refining

The number of workers employed in the refining branch of the petroleum industry increased from 74,821 in 1933 to 126,365 in 1945, and during the period the severity rate decreased from 2.10 in 1933 to 1.20 in 1945, which was the lowest rate attained. The previous low rate was 1.21 in 1942, but this was followed by 1.35 in 1943 and 1.75 in 1944. The accident-frequency rate for 1943, 1944, and 1945 is approximately the same as in 1933 and 1934, when the rates were 11.87 and 10.63, respectively. The rate decreased steadily until 1940 when it was 8.25; the rate in 1944 was 11.22 and 10.98 in 1945 (table 85).

TABLE 85. - Employment and accident data of the refining branch of the petroleum industry

Year	Number of workers	Number of workers: Per fatality	Number of workers: Per disabling injury	Injury rates: Frequency	Injury rates: Severity
1927	34,761	1,511	24	16.49	2.30
1933	74,821	2,078	45	11.87	2.10
1934	76,735	3,069	50	10.63	1.60
1935	86,967	3,623	56	9.46	1.38
1936	91,312	2,945	56	9.50	1.61
1937	95,976	3,428	58	8.91	1.35
1938	91,981	3,172	59	8.78	1.46
1939	92,427	3,187	59	8.56	1.39
1940	96,755	3,225	62	8.25	1.43
1941	100,131	2,225	60	8.45	1.82
1942	107,215	3,697	56	8.77	1.21
1943	112,793	2,751	41	10.75	1.35
1944	123,931	1,936	37	11.22	1.75
1945	126,365	3,159	38	10.98	1.20

Over-all Accident Rate of the Petroleum Industry

Some of the branches of the petroleum industry are not included in this discussion of safety in that field, as they are related only in a general way; the more important of these branches are the pipe lines, marine transportation, natural-gasoline production, and marketing, both wholesale and retail. However, the over-all accident record of the entire industry is shown in table 86. There has been little change in the frequency rate for accidents in the 13-year period 1933-1945; the frequency rate was 13.00 in 1933, 14.60 in 1937, and 14.43 in 1945. The severity rate decreased almost steadily from 1.90 in 1933 to 1.30 in 1943, but it was 1.46 in 1944 and 1.35 in 1945.

The reduction in the severity rate for accidents is significant, inasmuch as it indicates a decreasing amount of lost time per accident; possibly the smaller improvement in frequency rate is due, at least in part, to the fact that reporting has been more complete in recent years than in the past. Reference to the statistics shown in the various tables relative to the petroleum industry for 1927 show that a marked over-all improvement has been made in the general safety record of the industry.

TABLE 86. - Employment and accident data for all branches of the petroleum industry

Year	Number of workers	Number of workers		Injury rates	
		Per fatality	Per disabling injury	Frequency	Severity
1927	88,572	1,476	11	31.15	2.65
1933	274,294	2,312	36	13.00	1.90
1934	285,294	2,801	33	14.31	1.69
1935	303,982	3,039	33	13.96	1.55
1936	304,147	2,432	33	14.55	1.89
1937	324,956	2,708	33	14.60	1.67
1938	316,987	2,733	38	12.64	1.59
1939	315,731	3,222	40	11.96	1.41
1940	327,112	3,239	41	11.59	1.44
1941	333,122	2,948	41	11.78	1.44
1942	335,328	3,224	40	11.72	1.31
1943	335,570	2,970	34	12.87	1.30
1944	346,140	2,545	31	13.57	1.46
1945	368,133	2,922	29	14.43	1.35

For many years the petroleum industry has been cognizant of the basic importance of operating with regard to the safety of employees and plant as well. Relatively few petroleum companies, large or small, have failed to establish some type of agency with the forwarding of health and safety as a primary continuing activity. Over the years the Bureau of Mines has cooperated relatively closely with the petroleum industry in its safety work, and numerous Bureau of Mines publications have been issued as a result. One of the Bureau of Mines safety procedures that has been adopted to very good advantage is the training of employees in first aid to the injured, a very effective type of accident-prevention procedure if the training is done efficiently; to January 1, 1948, more than 150,000 employees of petroleum companies have taken the Bureau of Mines first-aid course, and it is confidently believed that hundreds of lives have been saved in the petroleum industry through this one activity. At one time, one petroleum plant had more than 5,000 personnel trained in first-aid. Numerous other safety and health procedures have been handled cooperatively by the petroleum industry and the United States Bureau of Mines.

The petroleum industry has established some extremely meritorious safety records by individual companies or in individual plants and areas, and the records of the Joseph A. Holmes Safety Association are replete with information about the numerous awards given to units of the petroleum industry during the past 20 years. Scores of petroleum plants, units, or areas have worked 500,000 or more man-hours without a lost-time accident; dozens have worked 1,000,000 or more man-hours without a lost-time accident, and at least one plant has worked more than 5,000,000 man-hours without a lost time accident to its full complement of workers, totaling over 8,000. One petroleum company had 8 different units, every one with 1,000,000 or more man-hours of exposure without a lost-time accident. These fine safety records in the petroleum industry come from several States, from both large and small organizations, and from almost all types of activity in the petroleum industry.

HEALTH OF MINERS

It has long been recognized that nearly all matters pertaining to health, safety, and efficiency in the mineral industries are so inherently interlocked that any attempt to try to engage in any one without paying due attention to the others is almost certain to result in ineffectiveness if not in absolute disaster. Hence, Bureau of Mines employees in the Health and Safety Division are prone to associate all three of these phases of mining when any one is brought up for discussion or action; and most of the hundreds of pamphlets issued by the health and safety workers of the Bureau of Mines since its inception in 1910 have recognized this interdependence in some manner.

No major industry has any greater need to safeguard the health and safety of workers than has mining, and it is generally admitted that mining is an ultra-hazardous occupation requiring exercise of the utmost precautions at all times, if the health and safety of the workers as well as productive efficiency are to be even fairly well protected. Mine workers are subject to essentially all of the ills and ailments that affect persons who engage in productive work on the surface; in addition, they are confronted with definitely unusual health problems almost wholly related to their atmospheric environment and other surrounding conditions.

Health is the greates asset of miners, as it is of all human beings. To miners, however, it probably is relatively more valuable than to most people, as their occupation almost invariably demands more than ordinary physical ability, particularly endurance; in other words, miners must be "he-men." When their health fails, they usually are relegated to the scrap heap; for this reason, many ex-miners, some of them at a relatively early age, especially in the past, have become watchmen, truck farmers, chicken raisers, or owners of taverns or pool halls, or have become engaged in some similar occupation.

As regards health, miners have some advantages as well as numerous very definite disadvantages over persons engaged in other types of industrial endeavor. Virtually all miners are forced to take considerable exercise, and our medical authorities tell us that only through exercise can good circulation of the blood and the efficiency of the various vital organs be maintained.

Any person who loads 6 to 10 or possibly 20 tons of coal or rock per day using a shovel or who "wrestles" all day with a several-hundred-pound drill or a several-thousand-pound mining machine, or who follows a mule or even a locomotive in hauling scores of cars of coal or rock, or who walks or partly runs through several miles of muddy, low, or hot underground workings, or who climbs several hundred or possibly several thousand feet of ladders per day certainly expends much physical effort and undoubtedly derives numerous advantages (as well as some disadvantages) over those whose work is sedentary.

In general, mine workers in reasonably well-conducted mines, especially in bituminous-coal mines, have almost ideal working conditions as regards temperature and humidity. The underground temperature of the air at the working places is usually around 60° F. (generally between 50° and 70° F.), and the relative humidity is around 80 or 90 percent, both temperature and humidity conditions being ideal for health and for efficiency in the performance of work. In most mines the temperature is essentially constant throughout the hour, day, week, or year; any variation is relatively slight, and underground workers are usually free of danger or inconvenience from heat or cold, rain or snow, and wind on the surface.

There are exceptions, however. In many deep mines the temperature is high; in others, both temperature and humidity are high; and in shallow mines the workings are often affected by outside climatic conditions, including, to some extent, winds.

Coal mines, in general, have "good" air and far better ventilation systems than other types of underground operations, owing largely to the fear of explosive gas even when it is not actually present; State regulations as well as the desire for self-preservation of the mine and the workers in it point out the advisability of ventilating. Most coal mines, therefore, have definite and fairly effective ventilating systems, and the chemical quality of the air is usually excellent. Ordinarily, the oxygen content of the air of coal-mine working places is over 20 percent, carbon dioxide is less than 1 percent, and toxic gases are usually absent.

Every year, however, the Bureau of Mines field men find scores of instances in which air in working places of supposedly well-ventilated coal and noncoal mines contains less than 20 percent oxygen (in some instances below 18 percent) and more than 1 percent or even as high as 2 or 3 percent carbon dioxide. During the past few years far too many samples of air taken at working places of coal and noncoal mines have contained the very toxic carbon monoxide gas in definite quantities (0.01 to 0.03 percent), this gas is found usually in poorly ventilated places in coal mines in which black blasting powder or its supposedly "safer" alternative, pellet powder, is used, or where dynamite is used in noncoal mines or even some coal mines. More than 1 percent of methane is rarely found in coal-mine working places, though there are occasional instances in both anthracite and bituminous mines (especially in anthracite mines with pitching beds) of asphyxiation of workers upon entering atmospheres containing so much methane as to reduce the oxygen content below respiratory requirements; unconsciousness or death is due to lack of oxygen rather than to the high methane content. In some coal mines sulfur gases such as H_2S or SO_2 are released by water inflow, and occasionally the gases occur in lethal percentages.

The air in working places of metal or nonmetallic-mineral mines is far more likely to be chemically deficient or contaminated than is that in coal mines owing to the fact that noncoal mines are supposed to be free of explosive gas (though explosive gas actually is found in some noncoal-mine workings); hence, neither the State laws nor consideration of protective expediency forces them to install, maintain, and operate really efficient ventilation systems. As a consequence, in many noncoal-mine workings where there is little or no effective air circulation, one is likely at almost any time to find air containing less than 18 percent of oxygen or 1 or more percent of carbon dioxide or various kinds of noxious fumes, such as carbon monoxide, oxides of nitrogen, or various sulfur gases from blasting with dynamite and fuse or released from water infiltration from strata. In addition, some noncoal mines, especially small operations, use steam or gasoline engines of various types underground, and the workings are almost certain to be more or less contaminated at times with poisonous gases; numerous deaths occur nearly every year through use of gasoline-driven equipment in small mines, especially in the driving or dewatering of shallow shafts.

The air of mine working places, although sometimes containing abnormal gas constituents, is not generally so impure as to menace the health of workers; yet it often contains enough carbon monoxide to cause headaches or other more serious symptons and occasionally enough to cause death in both coal and noncoal mines. In some instances, mine air becomes so deficient in oxygen that it causes workers to exert undue effort in their labor; in others it causes serious physical symptons and even unconsciousness or death. Distinctly poisonous gases, such as hydrogen sulfide, sulfur dioxide, oxides of nitrogen, and numerous others, are found occasionally, sometimes causing relatively light symptons - more or less serious irritation of the eyes, throat, or lungs or serious permanent physical or physiological effects and even death.

Some mines are definitely wet throughout, and many have some workings that are wet; but by far the greatest number of underground workers have dry surroundings in which to labor. Although wet workings usually have some advantages and some equally definite disadvantages as regards the effect upon health of miners, dry working places also have both good and bad features; unquestionably, the more pleasant working conditions in dry places carry with them far greater health and safety hazards to underground workers than do the wet places.

Wet places in a mine may merely be workings with water or mud on the floor, or there may be workings in which water falls through the air like rain, ranging from a drizzle to a downpour. The ill effects upon health vary; in certain lead-ore mines the water may carry lead compounds in solution and cause lead poisoning in the workers. Under some conditions in copper mines copper salts are dissolved in the water, and the workers have what are termed as "copper sores", and unless their feet are well protected from the water they may become too sore for walking. The copper sores, however, afflict various parts of the body subject to contact with the mineral-impregnated water. Where the water and air are cold (the temperature of some metal mines is around or even lower than 40° F.), many workers are subject to respiratory trouble, such as bronchitis or pneumonia, or have rheumatism. In wet mines having high temperature (many metal mines have air and water temperatures up to or over 100° F. and a few around or over 150° F.) the workers may be afflicted from time to time with boils or become weakened from too profuse perspiration or from undue heart strain; in wet mines in climates with really cold winters, the workers often suffer undue exposure in wet clothing in travel to the surface or upon coming to the surface unless extraordinary precautionary measures are taken.

Although those who work in wet places in mines thus have some health hazards and their work usually is done under decidedly unpleasant conditions, they ordinarily escape the real scourge of the miner, the dust hazard, to which nearly every underground worker in dry mines or even in dry places in wet mines is subjected. In wet coal mines workers have relatively little fear of the widespread coal-dust explosion, which may snuff out the lives of all in the mine; nor do they fear that their lungs or bronchial tubes or throat may become incapacitated through breathing very finely divided dust particles floating in the air. Workers in wet mines, whether producing coal or other material, have the satisfaction of knowing that miners' consumption or so-called miners' asthma is not likely to afflict them and carry them to an untimely death.

In mines that are dry, or in dry places in mines that might be termed "wet," in general nearly all ordinary mining processes tend to produce or disseminate dust. Certainly, blasting, shoveling, hauling, timbering, dry drilling, chute loading, and other activities in dry metal or nonmetallic-mineral mines are dust producers; likewise, blasting, drilling, shoveling, cutting, machine loading, hauling, and other essential coal-mining activities tend to "make" dust. In both coal mines and dry noncoal mines, much of the dust is very fine and is in suspension in the air breathed by the workers.

For generations it has been known that under some conditions breathing certain kinds of dusts has a harmful effect upon the health, and much has been written about dust diseases such as silicosis from breathing siliceous dust, anthracosis from breathing anthracite dust, siderosis from iron-ore dust, asbestosis from asbestos, etc. The term that indicates dust disease, in general, is "pneumoconiosis," and as a matter of fact this is very probably the term that should be applied to any dust disease that affects the lungs or lung passages. There is good reason to believe that no one particular dust is entirely responsible for any of the dust diseases, such as silicosis, anthracosis, siderosis, or others of like nature.

After more than 30 years of study of the engineering phases of dust diseases in mining, which included the taking of air-dust and other samples and readings of various kinds in many thousands of mine working places in coal, metal, and nonmetallic-mineral mines, it appears to be probable that breathing large quantities of relatively finely divided dust over long periods ultimately will harm the health. Such dusts include not only siliceous dust (whether as free silica or in combined form as silicates or otherwise), but also bituminous-coal or anthracite dust and dusts of iron ore, limestone, alumina, or any other mine dust, or any or all combinations of these dusts.

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Moreover, the dust problem, as regards health and safety in coal mining and health in noncoal mines, is or should be almost entirely an engineering and operating problem. It now is used largely as a type of racket in which the victims of dust disease get little or no relief, financial or otherwise, and the mine operators, chiefly through their own sins of omission, are harassed by lawsuits or foolish regulations. Moreover, well-meaning but poorly informed lawmaking bodies or investigating committees promulgate regulations or laws on dust disease, chiefly silicosis (an ailment that cannot be diagnosed accurately), when, as a matter of fact, no definite data are available concerning numerous essential factors, such as the kind of dust that will induce silicosis or pneumoconiosis, or the size, number, or weight of the particles, or the percentage of silica in any dust to make it harmful, as well as numerous other data essential to a really correct determination of the definite cause of the injury to the health of the victim, even though the injury itself may be readily apparent.

With our decidedly limited knowledge of the facts underlying causation of dust diseases, the only safe method of handling the problem at present is to accept the idea that the long-continued breathing of air containing large quantities of very finely divided dust will almost certainly have harmful physical effects sooner or later to mine workers who breathe the dust and that the only known "cure" is the prevention or limitation of the occurrence of dust in mines. This is an engineering-operating problem entirely within the control of those who operate or work in mines.

The introduction of rock dust into coal mines to prevent or to limit explosions is a long step toward coal-mine safety and, if done with judgment, need not introduce any additional health hazard into coal mines. If the face regions and floor of main haulage roads of our dry coal mines are kept well watered and rock dust is applied to all other accessible surfaces, there will be little or no health hazard other than possibly to the persons who do the rock dusting, and those persons can be protected by taking precautions against breathing heavy concentrations of dust more or less continuously. Water should be piped to all dry faces in coal mines and used on the cutting machine while undercutting, overcutting, centercutting, or shearing, and the face worker should sprinkle the face region within 40 or 50 feet of the face (ribs, roof, floor, and coal pile) at least three times daily, as well as sprinkle (not soak) the tops of all loaded cars before they leave the face. The floors of main haulage roads also should be kept wet. Those who apply the rock dust should use respirators or otherwise take precautions not to breathe heavy concentrations of any kind of rock dust for long periods day after day.

Sanitation in and around mines has been improved considerably in recent years, but in the majority of both coal and metal mines and mining communities much remains to be done before the miners or their families can truthfully be said to work or live under up-to-date sanitary conditions. Sewage conditions, although fair in some metal mines and good in some so-called model mining communities, in general may be termed deplorable without exaggeration. In coal mines any attempt to remedy such conditions would be ridiculed by the workers as childish or effeminate, although many metal miners are inclined to react favorably to rules, regulations, equipment, or devices designed to improve underground sewage conditions.

Housing as well as sewage conditions in many mining communities constitute ample warrant for continuing to use the designation "mining camp," even though the mining industry may resent the term. The mines of the United States, with some exceptions, have not had the assurance of stability of operation or length of life to justify the necessary expenditure for really good sanitary conditions in mining communities; these include such features as sewers, city water systems, concrete roads and sidewalks, lawns, brick or concrete houses equipped with baths, running water, and other conveniences once considered luxuries but now regarded as necessities, especially in town or city life. Many fairly progressive mines have failed to provide a usable wash house, though some mining companies have wash houses or "drys" that resemble palaces; in general, not enough attention has been given to this important matter at mines in the United States. Provision by the companies of better welfare and sanitation facilities, including houses, amusement halls, washing, bathing, and latrine accommodations at mines, and sewage facilities in mining camps, city water systems, and other like features for workers and their families very likely would not only pay well in the satisfaction they bring to those who work in mines but would also pay well in dollars and cents, in cooperative spirit which they bring sooner or later with decrease in labor turnover, and with numerous advantages brought about by attracting recruits to the industry, the latter being of utmost importance in the post-war period.

In the coal mines of the United States education regarding the dust hazard is needed badly. The coal-mining public, instead of "standing pat" and referring to out-of-date and often misleading foreign statistics that coal dust is harmless to health or is even healthful, or accepting equally misleading opinions of so-called dust experts that only one or possibly a few dusts can be considered harmful should make impartial and comprehensive studies of dust conditions in coal mines (anthracite, bituminous, and lignite), paying particular attention to examination of the nose, throat, and chest conditions; coal-camp doctors who have or at least should have direct knowledge of the harmfulness of coal dust to underground workers, especially those working on mining, loading, or hauling machines, should write technical articles describing the true situation; and State and Federal authorities as well as other interested agencies should cooperate in making studies and publishing results on the health of workers in dusty places in all types of coal mines.

A relatively short presentation cannot adequately cover the essentials in trying to evaluate the results and accomplishments of the mining industry in its health and safety efforts for the benefit of those engaged in the mineral industries, although a glance through the bibliography of published matter, issued by the Bureau of Mines, covering investigations and their results with reference to health and safety in the mineral industries indicates to a certain extent what has been done as well as what has been attempted.

Statistical information as to health in the mineral industries, coal as well as noncoal, is so fragmentary as to be almost nonexistent. Nevertheless, although much has been done along the line of dust control in both coal and noncoal mines in the United States, very much remains to be done, and in the doing the harvest will be ample, both from a financial and a humanitarian point of view.

Does Safety and Health Work Pay?

The monetary savings earned through reducing the number of accidents and improving the health of the workers in the mining industry are difficult to ascertain in terms of dollars and cents, but some fairly accurate estimates are made by insurance companies and various associations as to individual mines or as to mines of individual mining companies.

As regards safety work, some definite nationwide figures are available and are offered. During the 5-year period 1906-1910, inclusive (just before the creation of the Bureau of Mines), 13,288 persons were killed in the coal mines of the United States, an average of 2,658 per year, and the fatality rate for this 5-year period was 5.89 persons killed per million tons of coal produced. In the 5 years 1941-1945, 6,580 persons were killed in the coal mines of the United States, and the fatality rate was 2.07 persons killed per million tons of coal produced; the fatality rate dropped 65 percent from the 5.89 rate of the period 1906-1910.

If the 5.89 fatality rate for the 5-year period 1906-1910 had continued to the first of January 1947, the number of fatalities from 1910 in the coal mines of the United States would have been at least 38,000 more than they actually were; hence, during the life of the Bureau of Mines to January 1, 1947 (36-1/2 years), the reduction in the coal-mine fatality rate indicates an average annual saving of life of more than 1,000 persons; similar figures on prevention of nonfatal accidents are not available, but it is estimated that over the years at least 50 nonfatal accidents occur to 1 fatality; hence, it is probable that about 50,000 nonfatal accidents also have been prevented annually. If the cost to the operator of a life is translated into cold-blooded dollars and cents and a relatively low amount, such as $5,000, is taken as the "value" of a life, it will readily be seen that, irrespective of ethical or humanitarian consideration (and omitting nonfatal accidents), the annual saving of somewhat more than 1,000 lives may be considered as "worth" more than $5,000,000, or about three times the total amount being expended by the Health and Safety Division of the Bureau of Mines annually during recent years, and at least 10 times as much as was spent on health and safety work in any year prior to 1935. If it also is conceded that as many as 50,000 nonfatal accidents per year have been prevented (the assumption is by no means unreasonable), and the "cost" to the operation in compensation, hospitalization, etc., of a nonfatal accident is placed at $100 (some authorities estimate it at a minimum of $300), it will be seen that at least an additional $5,000,000 annually has been saved to the coal industry through the increased safety efforts of the past 36-1/2 years.

Benefits to workers are even more impressive. Preventing the deaths of about 38,000 coal-mine workers in the past 36-1/2 years has obviously avoided a great deal of suffering, pain, and misery to their families, and the prevention of 50,000 or more nonfatal accidents annually for 36-1/2 years certainly has saved the miners, their families, their friends, and the community much pain, inconvenience, and misery, and other losses both ethical and monetary. The financial losses to workers that have been avoided through increased safety in coal-mine operation are colossal. The average age of the coal-mine worker who was killed in pre-war times was about 35 years; he should, under normal conditions, have a future of active work of at least 20 years. In normal times he should earn at least $1,000 annually; at present this figure is between $2,000 and $3,000. Hence, in his 20 years life expectancy he would receive at least $20,000 for his services. Thus, extending the lives of about 38,000 coal-mine workers in the past 36-1/2 years has prevented a financial loss to them of at least $760,000,000. This does not take into consideration the financial losses saved to the worker through the elimination of large number of nonfatal accidents. It thus appears tha more than $20,000,000 annually has been saved to the workers in coal mines through accident prevention. This is far more than the total expenditure on safety work made by the Federal Bureau of Mines between its establishment in 1910 and the advent of World War II; therefore, the coal-mine worker unquestionably is reaping annual dividends of several hundred (probably several thousand) percent on the expenditures of the Federal Government in the promotion of safety in coal mining.

Health and safety work (both research and service) in the mining and allied industries offers large remuneration in salvage of life and limb as well as in dollars and cents for dividends as well as capital investment. At present, questions in connection with occupational disease are harassing industry (both workers and employers), and mining is very deeply affected; much work should be done on the subject of dust alone, and the incentive here is one that taxes the imagination, as thousands of workers are incapacitated annually by dust disease, and hundreds die of it. Suits involving many millions of dollars have been in court recently in connection with dust disease in mines and tunnels, and this should be taken as a warning, because industrial workers in the United States are becoming increasingly dust conscious. Unquestionably, the prevention of dust disease in mining is a problem that can be solved, and the various ramifications of dust occurrence should be attacked constantly and vigorously. The Bureau of Mines undoubtedly is the best agency to handle most of this problem, not only in the field but in the research laboratory. Numerous other health and safety problems in the mining and allied industries also can and should be solved, and the Bureau of Mines is the logical organization to do much of the work in cooperation with those engaged in coal mining. In all kinds of mining, although much progress has been made during the past several years in promoting safety, and tangible evidence of this progress has been apparent during the past 5 or 6 years, there is no question but that accidents could be reduced at least 50 percent (possibly as much as 75 percent), in which event the financial savings would amount to millions of dollars annually to both workers and operators, to say nothing of the admittedly great humanitarian and sociological benefits that certainly would accrue to the entire Nation. Here, again, the Federal Bureau of Mines, with its vast experience and with a definite record of accomplishment, is the spark plug to keep the work functioning effectively. But to enable the Bureau of Mines to do a good job, the funds allotted to it for health and safety work should be increased severalfold, and at all times the cooperation of those engaged in the industry is absolutely indispensable.

The foregoing facts about the value of safety in coal mining are more or less true of other phases of mining and allied industries, all of which still have a relatively high rate of accident occurrence, though much progress has been made in the past several years.

The beneficial effects of the health work of the Bureau of Mines in cooperation with the mining industry can be no means be shown as readily in statistical form as can the effects of the safety work, but with respect to a considerable number of investigations by Bureau of Mines personnel of gases, dusts, temperatures, humidities, and other similar matters, definite information can be given not only as to their effect upon workers but also as to protective or preventive methods, devices, and procedures. The work of the Bureau regarding respiratory protective equipment is of utmost importance. Information given by it to the public as to the effect upon health of breathing gases (carbon monoxide, hydrogen sulfide, etc.) has not been exceeded by any other agency in the United States; its early work in dust constitutes the basis of information and teaching on these matters today in industrial work; and numerous other fundamental accomplishments could be mentioned, the details of which cannot be given in a short paper. Fortunately, the mining industry has used the available data, and as a result much good has been accomplished, even though much remains to be done.

TREND OF FATAL ACCIDENTS IN THE MINING INDUSTRY

Statistics on injuries (fatal and nonfatal) received annually by workers in the mining industry are important, as this is the only tangible means by which progress in safety in the industry can be measured. A reduction in fatal and nonfatal injuries over an extended period of years can justly be attributed to work that has been done to improve conditions and to make the mines safer.

Fatal-accident statistics are more inclusive and much more definitely comparable than nonfatal-accident statistics, as all States require fatal accidents to be reported to the proper authorities. Unfortunately, this is by no means universally true of nonfatal accidents, and there is wide variation in reporting them. The progress of safety in mining can be measured relatively well at present by the use of fatal-accident statistics, even though additional information is desirable.

Graphs and tables showing the annual fatality rates in the various branches of the mining industry are difficult to evaluate because of their wide fluctuation over a period of years, and in some cases they can give erroneous impressions unless care is taken in their interpretation. For this reason, trends or averages are useful in evaluating the over-all picture of accident occurrence. The following trends are determined mathematically by the method of least squares; the trends are based on the fatality rates per million tons produced and also on millions of man-hours exposure where the information is available.

Coal Mining

The trend of fatal accidents in coal mining (anthracite and bituminous), based upon deaths per millions of tons produced from 1906 to 1946, inclusive, is shown in figure 13. The trend indicates an over-all reduction of 67.5 percent in fatal accidents per million tons of coal produced in the 41-year period. The fatality trend based upon millions of man-hours is shown in

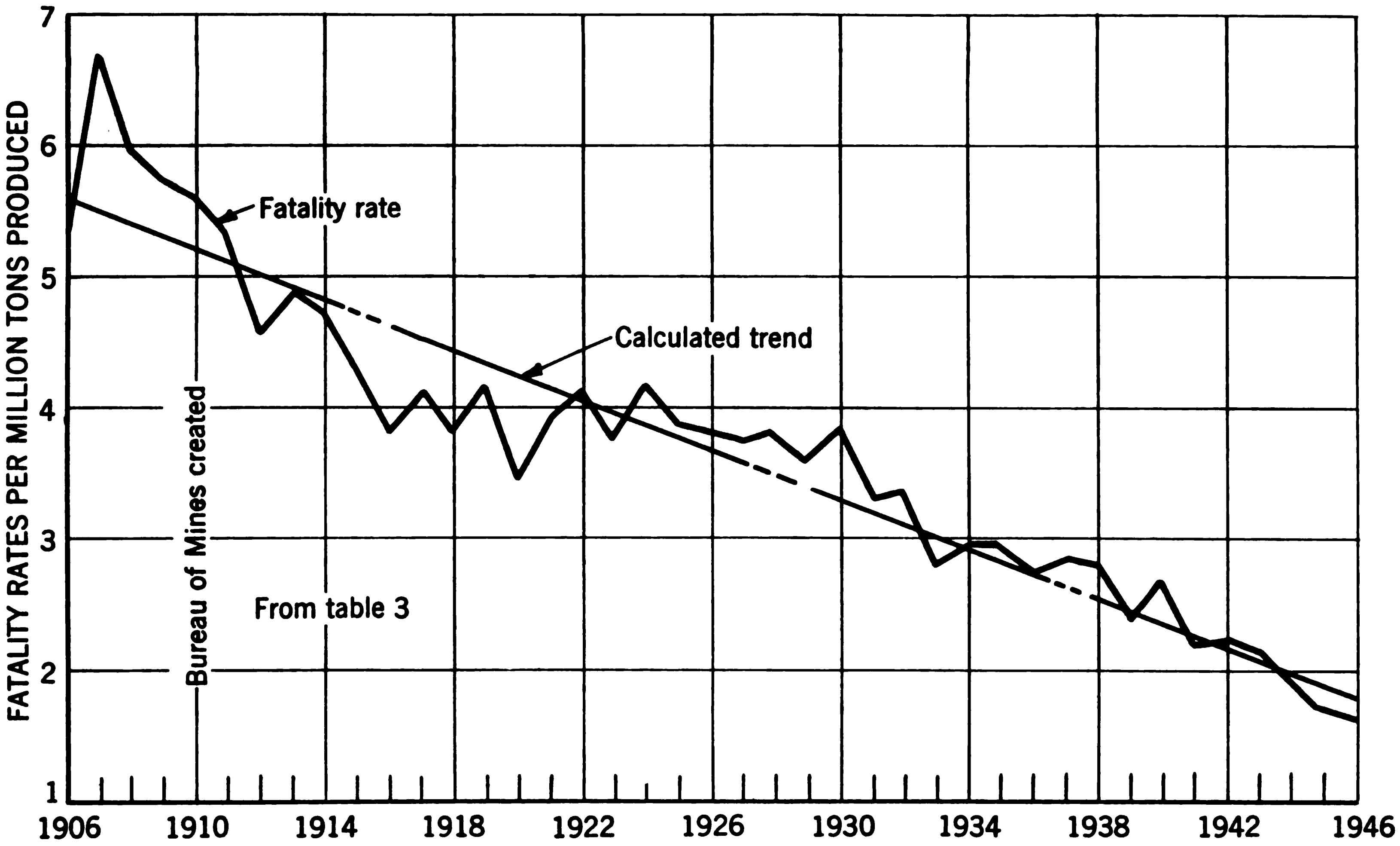

Figure 13. - Trend of fatal accidents at all coal mines, 1906-1946 (bituminous and anthracite).

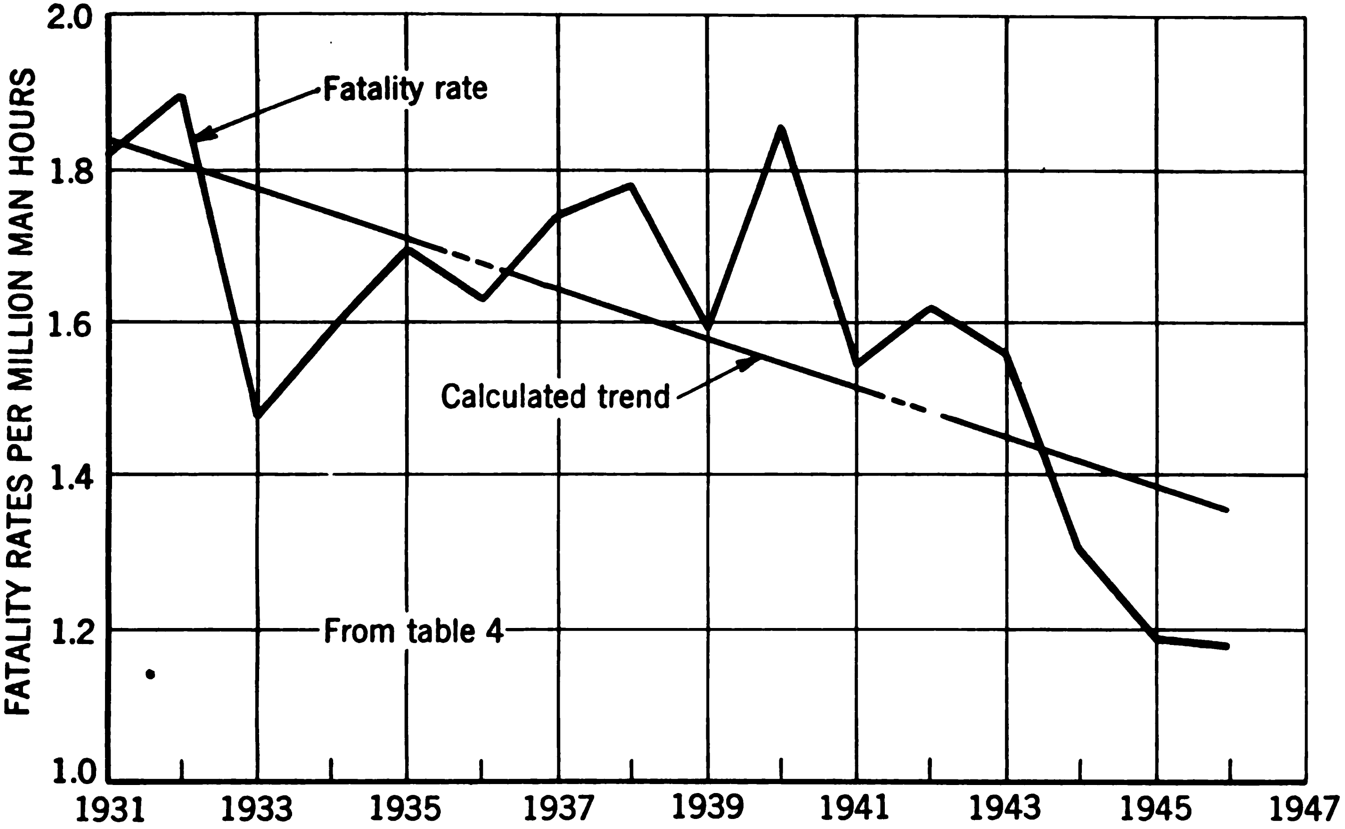

Figure 14. - Trend of fatal accidents in all coal mines (bituminous and anthracite) based on millions of man hours.

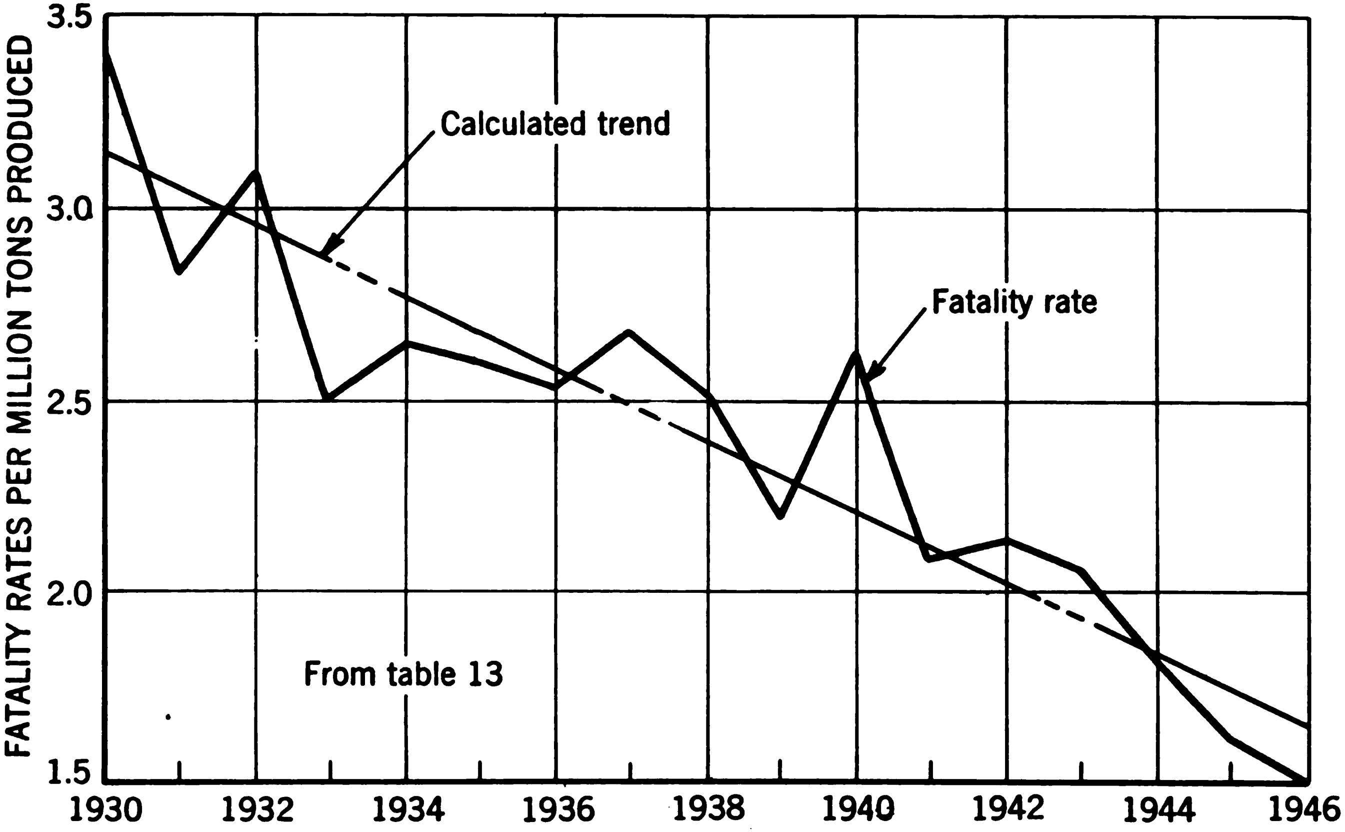

Figure 15. - Trend of fatal accidents, bituminous-coal and lignite mines, based on millions of tons produced.

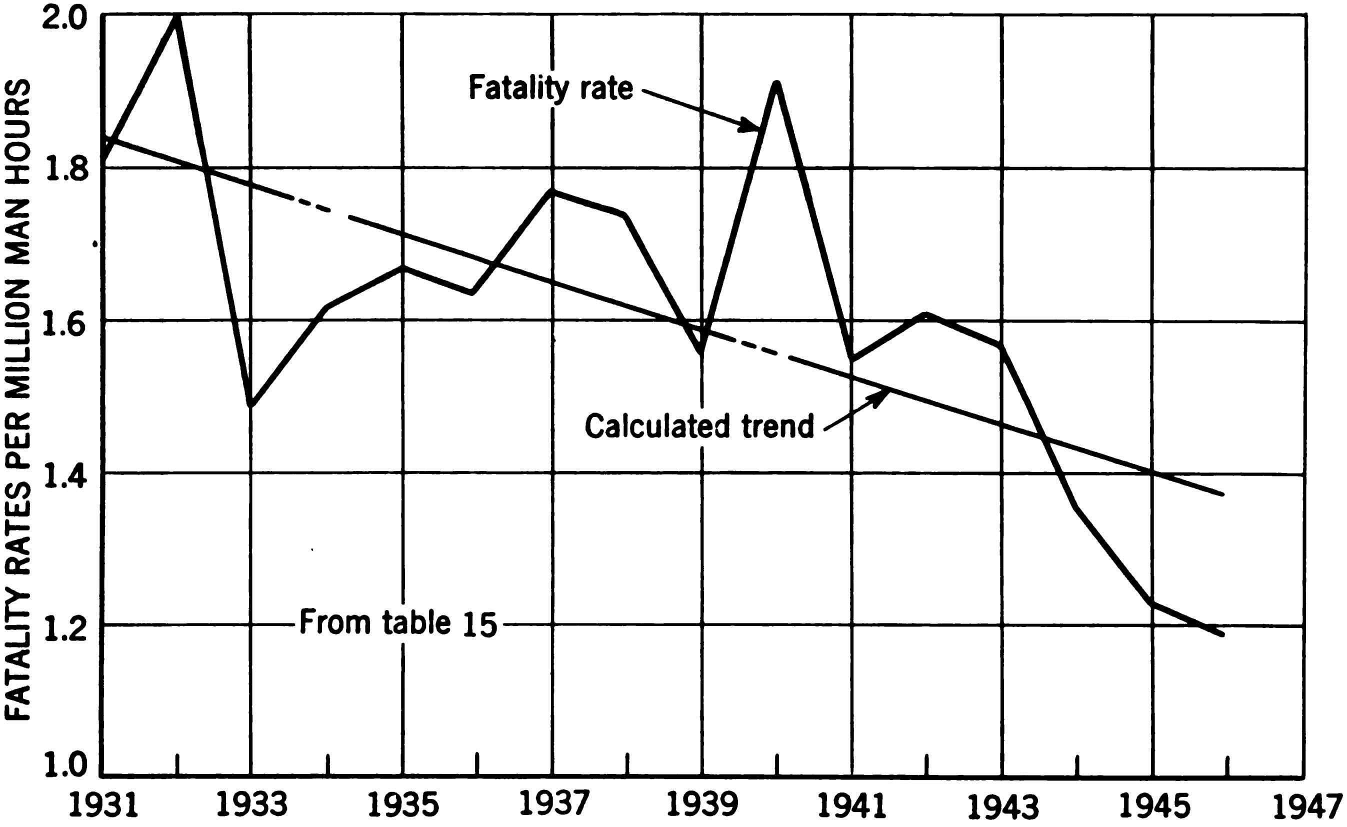

Figure 16. - Trend of fatal accidents, bituminous-coal and lignite mines, based on millions of man hours.

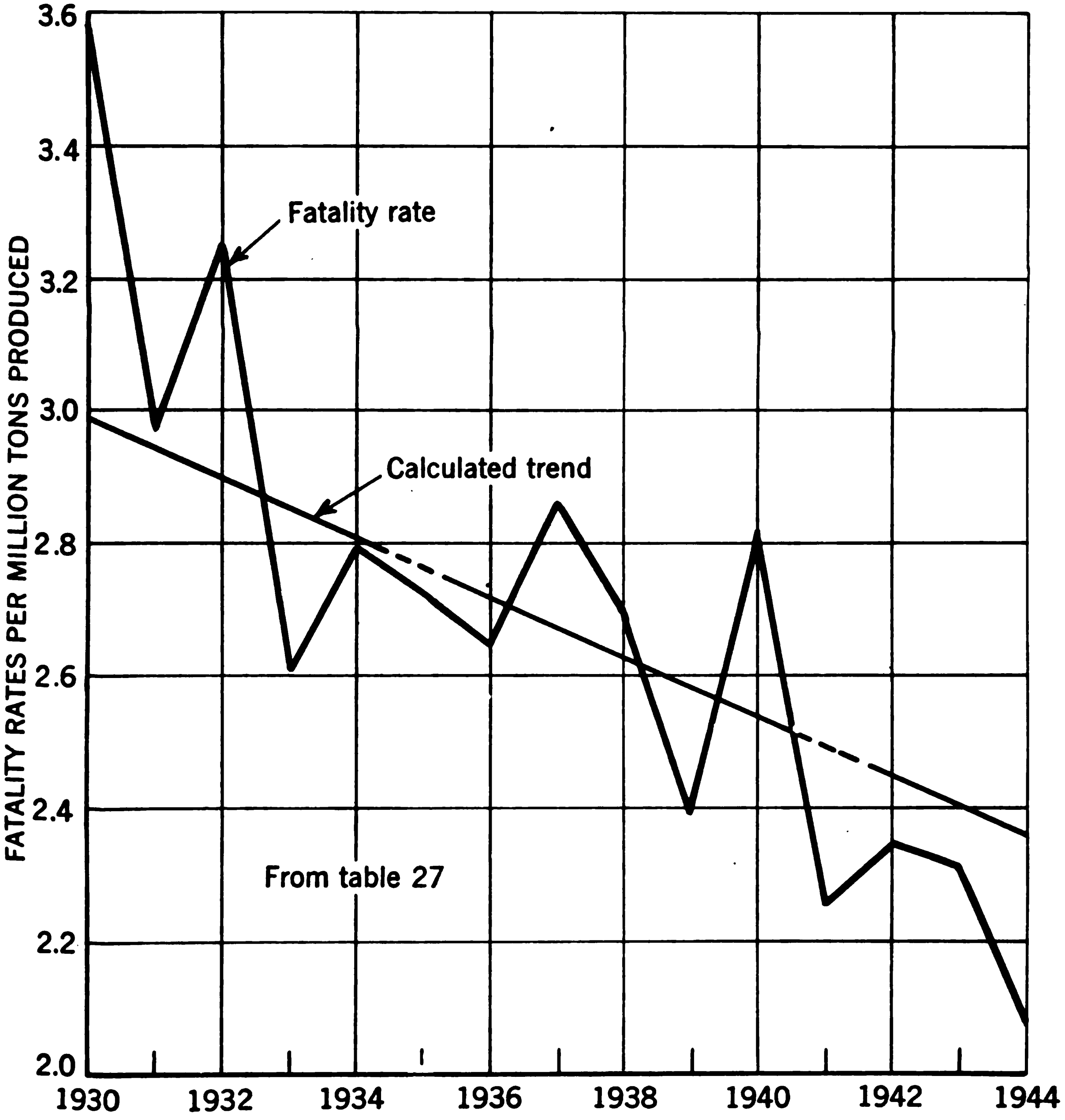

Figure 17. - Trend of fatal accidents, underground bituminous coal and lignite mines and surface plants, based on millions of tons produced.

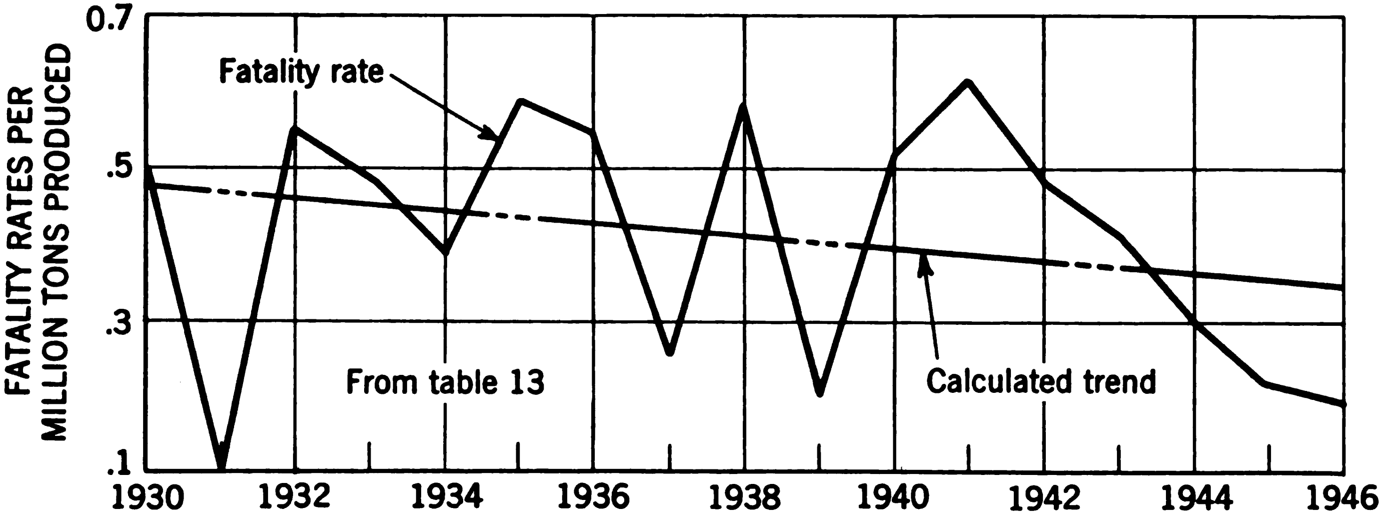

Figure 18. - Trend of fatal accidents, bituminous-coal and lignite strippings.

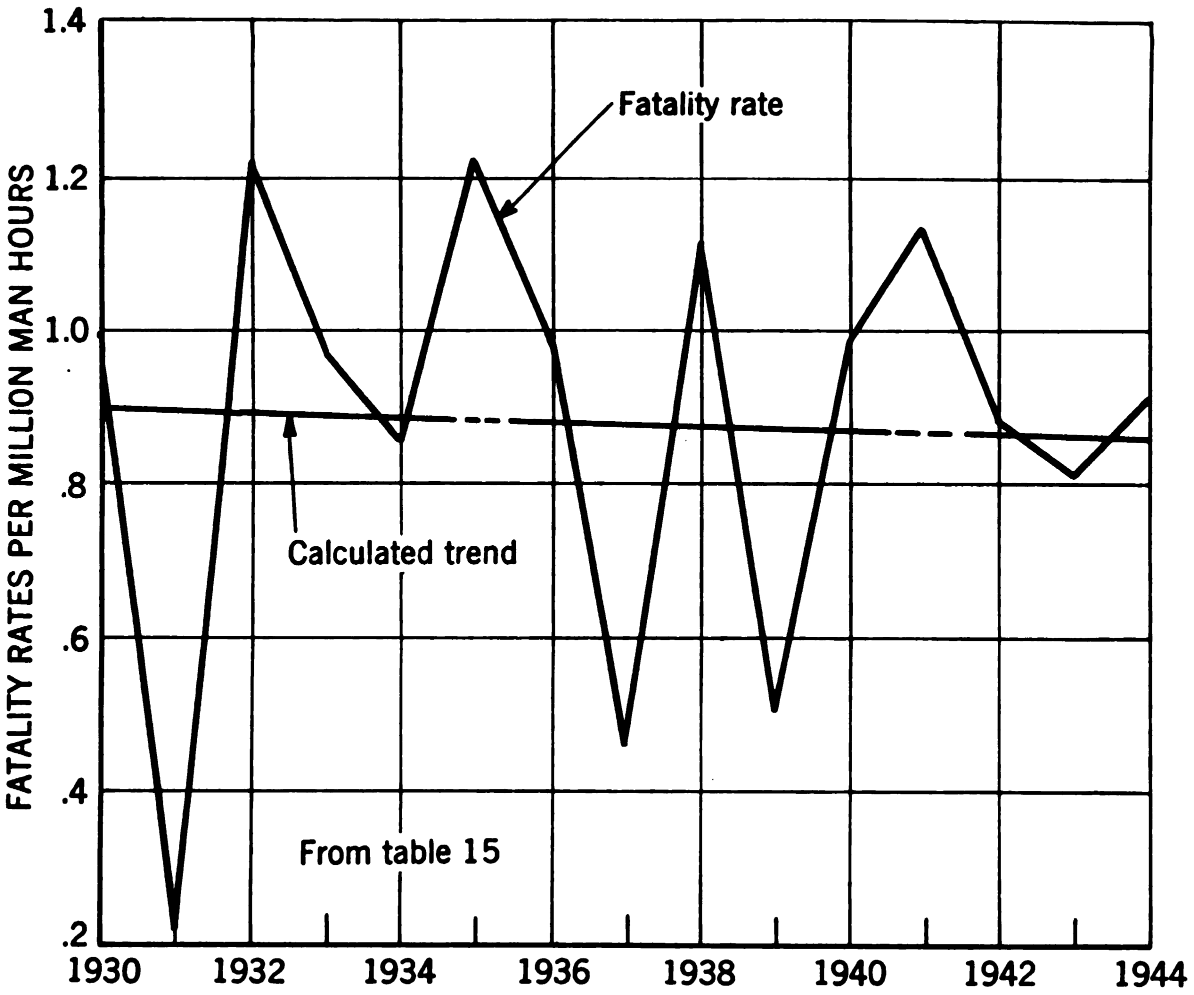

Figure 19. - Trend of fatal accidents, bituminous-coal and lignite strippings, based on millions of man hours.

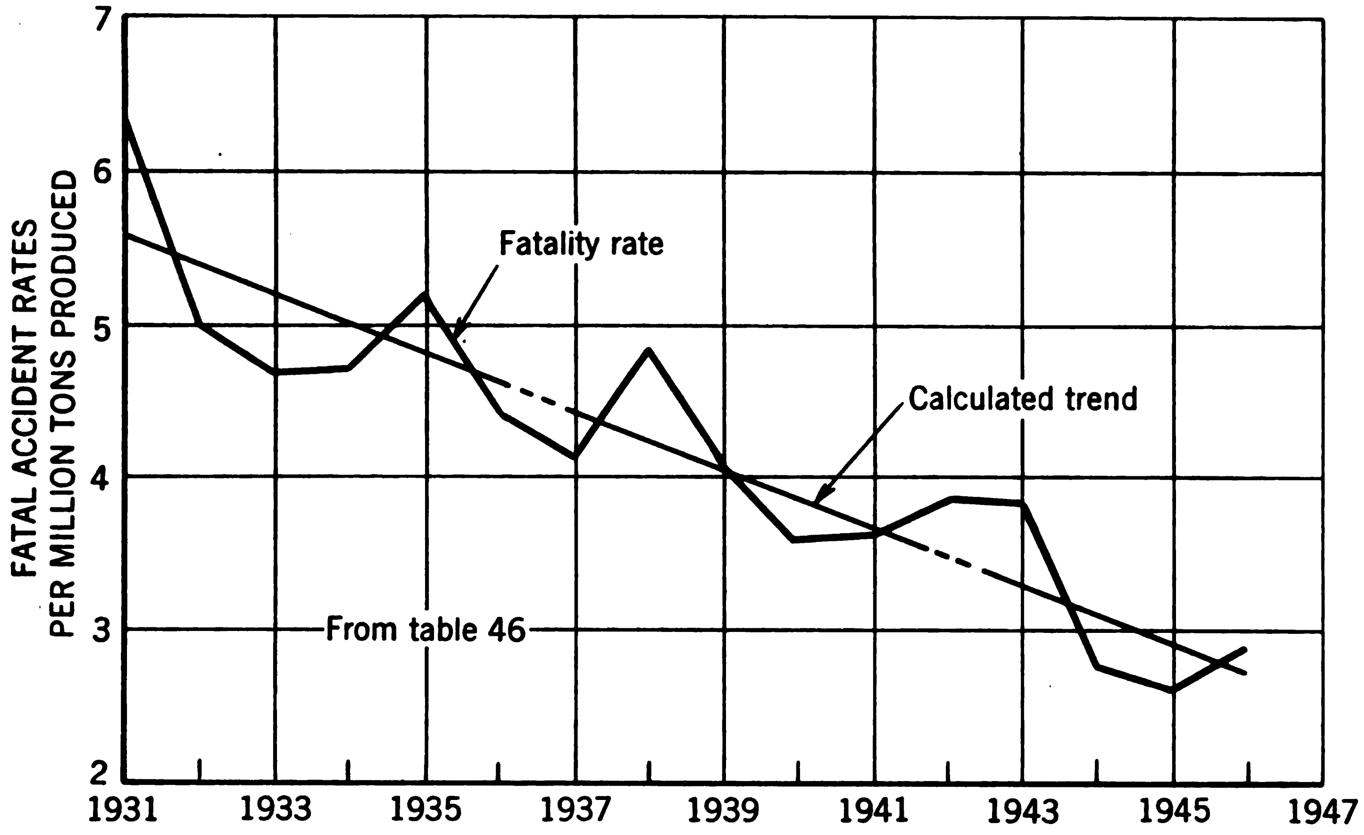

Figure 20. - Trend of fatal accidents, anthracite mines, based on millions of tons produced.

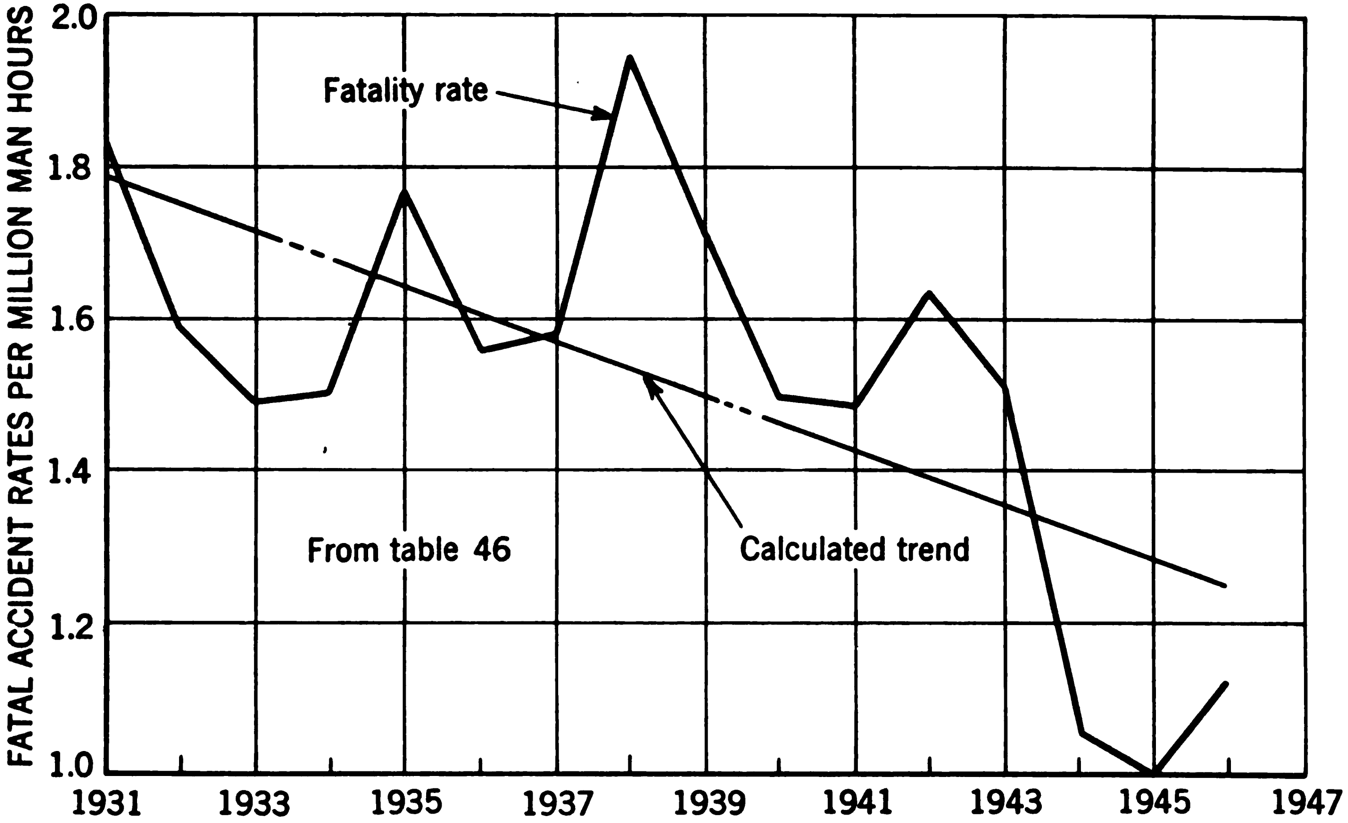

Figure 2l. - Trend of fatal accidents, anthracite mines, based on millions of man hours.

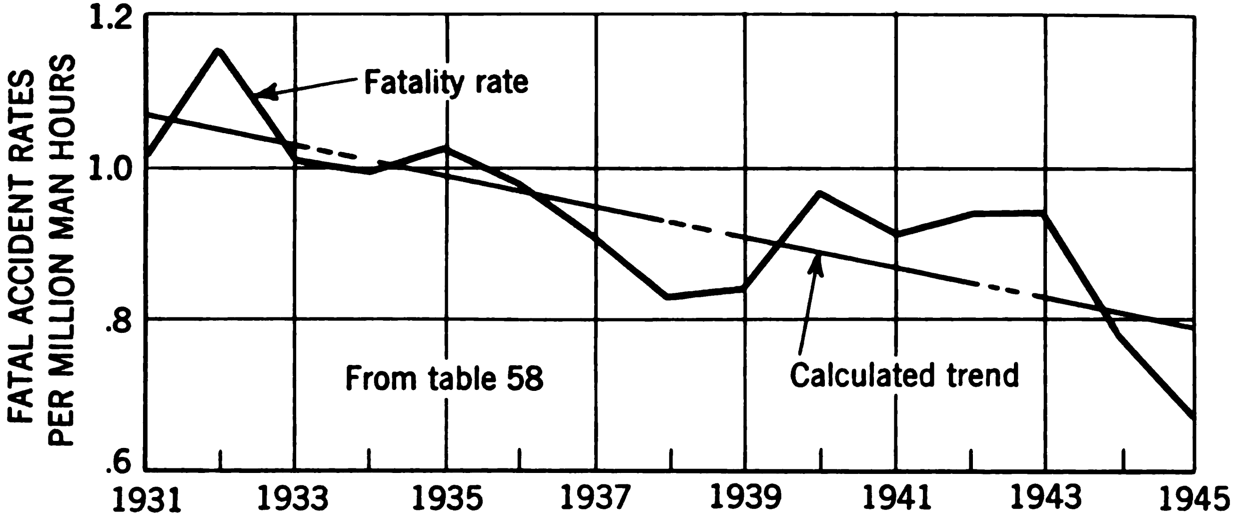

Figure 22. - Trend of fatal accidents, all mines except coal mines, based on millions of man hours.

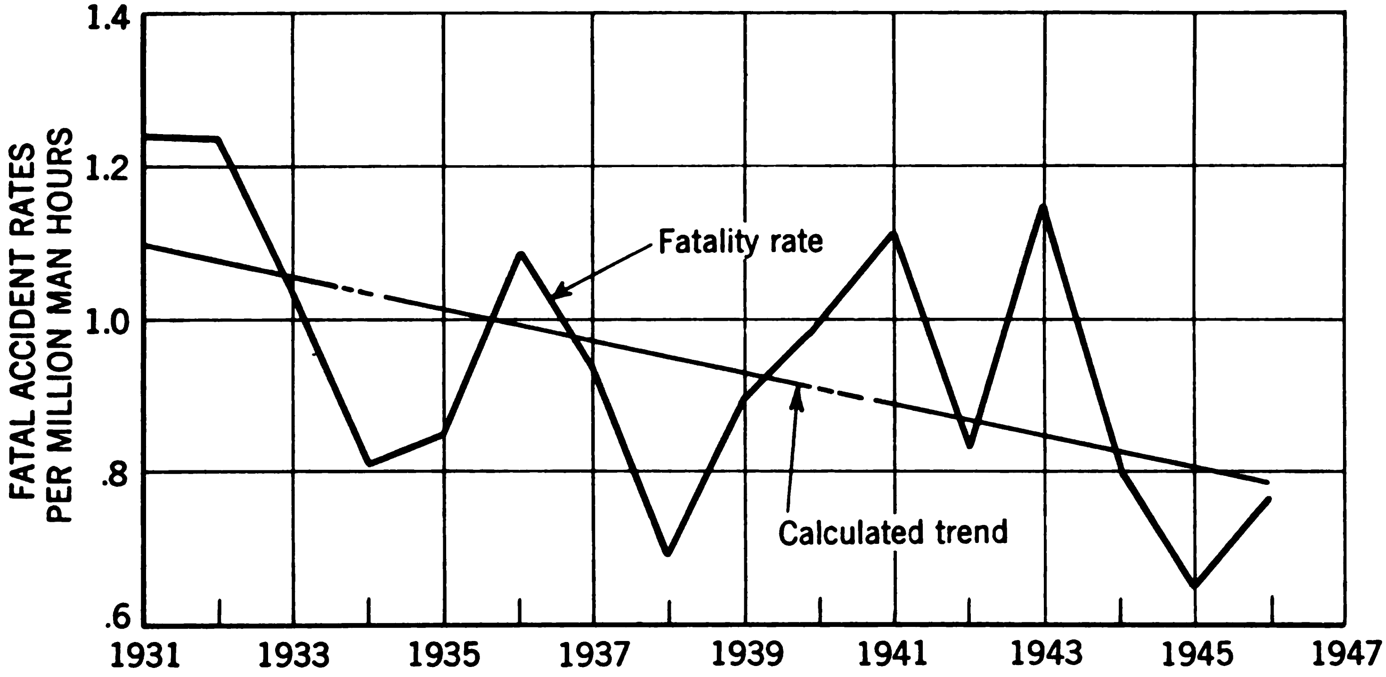

Figure 23. - Trend of fatal accidents, copper mines, based on millions of man hours.

figure 14. Man-hour statistics prior to 1931 are not available, hence the trend is based upon a 16-year period from 1931 to 1946, inclusive. It is noteworthy that both these trends show that material progress has been made in reducing fatality rates in the coal-mining industry of the United States.

Bituminous Coal and Lignite

The trend of fatality rates in bituminous-coal and lignite mines based upon deaths per million of tons of coal produced and upon millions of man-hours are shown in figures 15 and 16 for the period 1931 to 1946, inclusive. The trend in both instances shows a marked reduction in the fatality rates. Some of the reduction in fatality rates can be attributed to the larger amount of coal produced from coal strippings; however, the trend of fatal accidents in underground mines, including their surface plants, is shown in figure 17, and this also shows a marked reduction in the fatality rate per million tons of coal produced.

The trends of fatality rates in bituminous-coal and lignite strippings from 1930 to 1946, inclusive, based upon millions of tons of coal produced and upon millions of man-hours are shown in figures 18 and 19. They indicate that less progress has been made in reducing fatality rates in stripping operations than in underground mining.

Anthracite

The trends of fatal accidents in mining anthracite, based upon millions of tons produced and millions of man-hours from 1931 to 1946, inclusive, are shown in figures 20 and 21. The improvement in the safety record in this period is shown definitely by both methods of calculating the fatality rates.

Metal and Nonmetallic-mineral Mining

Statistics of accidents in metal and nonmetallic-mineral mining are based upon millions of man-hours of exposure; production in tons of material handled is not compiled by the Bureau of Mines.

The trend of fatalities at all mines except coal mines for the period 1931-1945 is definitely downward. (Fig. 22.) The fatal-accident rates per million man-hours of exposure have declined from a high of 1.16 in 1932 to 0.67 in 1945; during the same period the nonfatal-injury rate per million man-hours of exposure has declined from 55.76 in 1931 to 48.63 in 1945.

Statistics of accidents and employment in metal and nonmetallic-mineral mining, as compiled by the Bureau of Mines, are not as comprehensive as in coal mining, and relatively little detailed information is available.

The fatal-accident rate per million man-hours in copper mining had a definitely downward trend in the period 1931-1946. The rate has fluctuated from a high of 1.24 in 1931 and 1932 to a low of 0.65 in 1945 (fig. 23).

Iron mines have reduced the fatality rate appreciably in the last few years and have stopped the adverse trend reported by the Bureau of Mines in 1942. The trend line for the period 1931-1946 is virtually a level line (fig. 24). This may mean that these mines are approaching the irreducible minimum in their fatality rates, as these rates are relatively low.

The fatal-accident rates per million man-hours in the lead-zinc area of the Mississippi Valley have fluctuated more widely than any other group of mines. The trend for the period 1931-1945 is slightly upward, even though the rates of the past 5 years show a definite improvement over many previous years (fig. 25).

The trend of the fatal-accident rate at gold, silver, and miscellaneous metal mines was definitely downward from 1931 to 1945, inclusive. The rate established was 0.85 in 1944 and 0.57 in 1945, the lowest attained during the period (fig. 26).

The fatality rate per million man-hours of exposure at nonmetallic-mineral mines was lowered consistently from 1931 to 1936, but since 1936 the rate has increased. The trend has been definitely upward during recent years (fig. 27), and the need for more activity in accident prevention is apparent.

Quarrying

The quarrying industry as a whole has a much lower fatality rate per million man-hours of exposure than underground mining (as would be expected) and the trend is slightly downward (fig. 28) for the 16-year period 1931-1946.

The trend of fatalities from 1940 to 1946, inclusive, for the several branches of the quarrying industry is shown in figure 29. The trend of fatalities in the limestone industry is definitely upward and is largely responsible for the relatively small improvement in the record of the quarrying industry as a whole, as shown in figure 28.

RÉSUMÉ AND CONCLUSIONS

The mining industry seldom receives the publicity it deserves with respect to mine safety. Accidents and disasters are given wide publicity, and much is written about the dangers of mining, but progress in making mines safer has little news interest, as it is not spectacular enough to warrant headlines. The mining industry as a whole has made tremendous progress in accident prevention, and comparison of present-day fatal- and nonfatal-accident rates with those of a few decades ago proves this. Huge sums have been spent in accident-prevention work, and results prove that such expenditures have paid dividends, not only in money saved but in lives saved and prevention of suffering of workers. The monetary saving has compensated for far more than the cost of accident-prevention work, and had it not been for the immense strides in accident prevention in the mines of the United States it is improbable that this country would have been able to achieve the marvelous mineral production that undoubtedly enabled it and its allies to win World War II. At first, safety work had to be "sold" on the humanitarian basis and this was quite

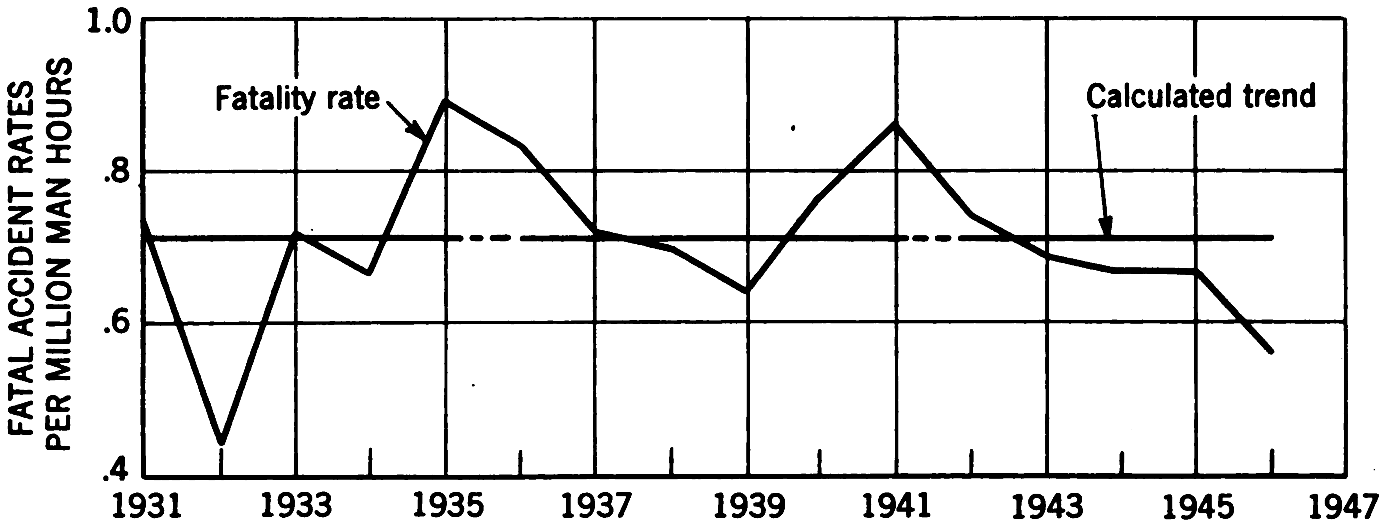

Figure 24. - Trend of fatal accidents, iron mines, based on millions of man hours.

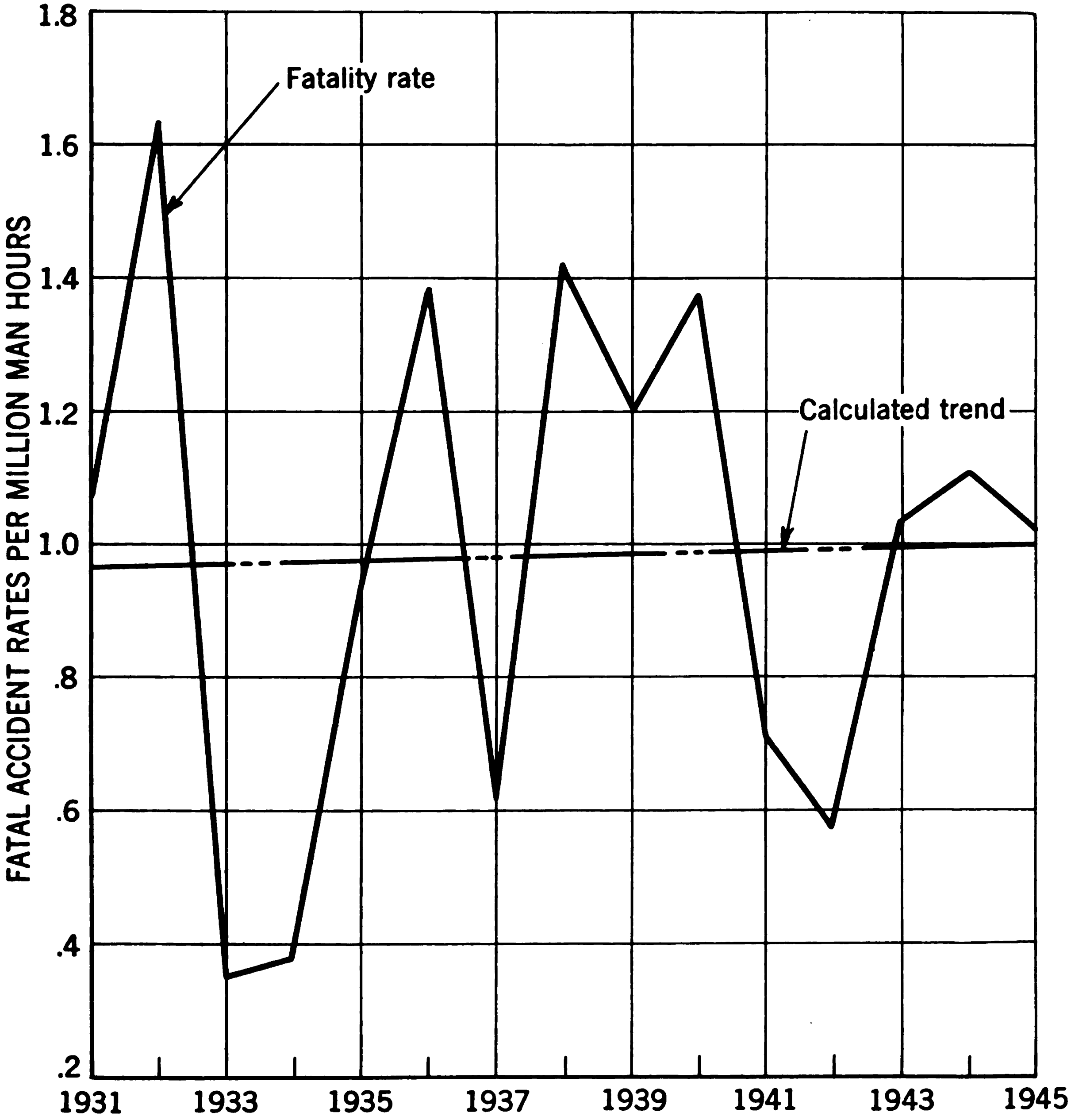

Figure 25. - Trend of fatal accidents, lead-zinc mines (Mississippi Valley), based on millions of man hours.

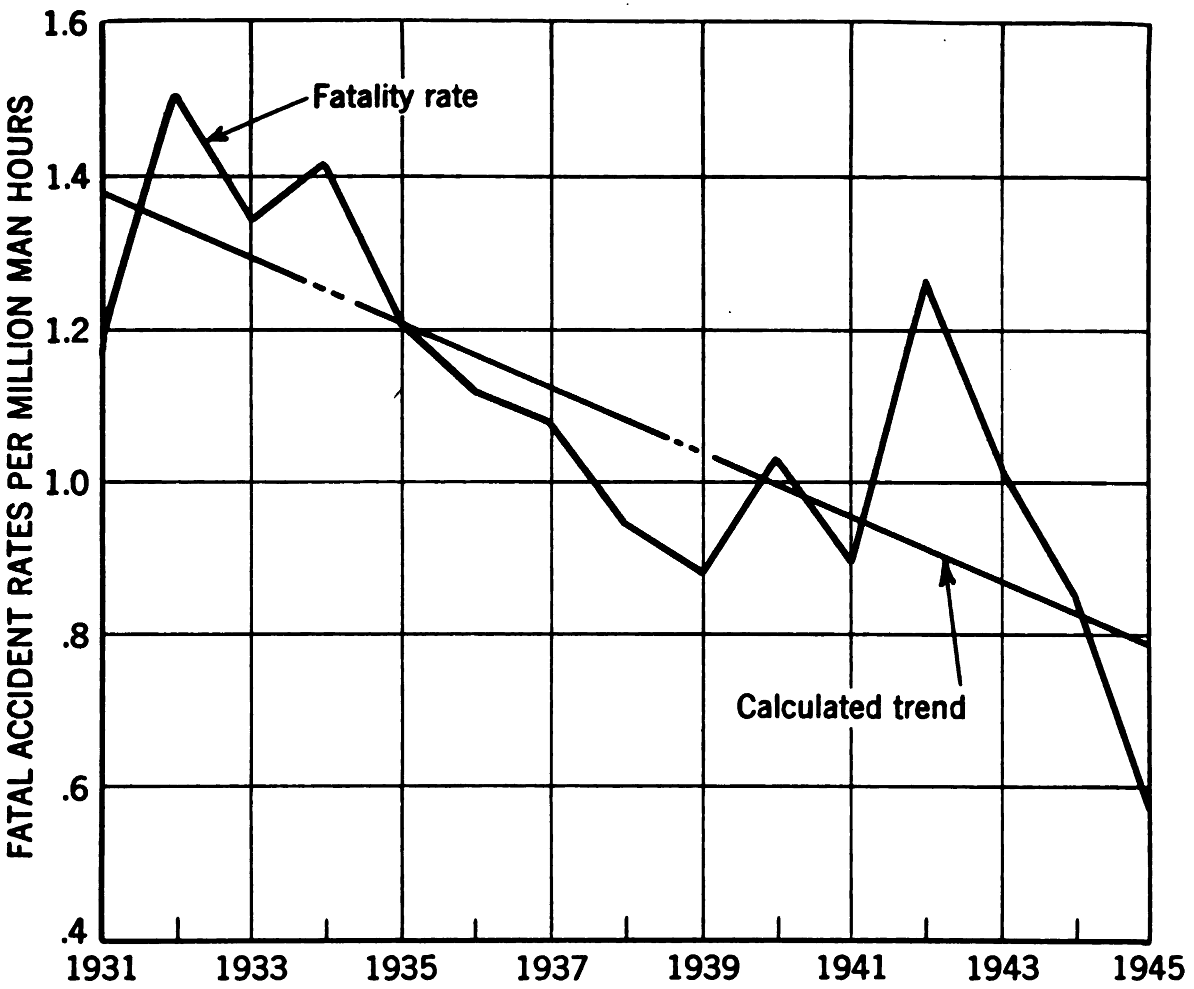

Figure 26. - Trend of fatal accidents, gold, silver and miscellaneous metal mines, based on millions of man hours.

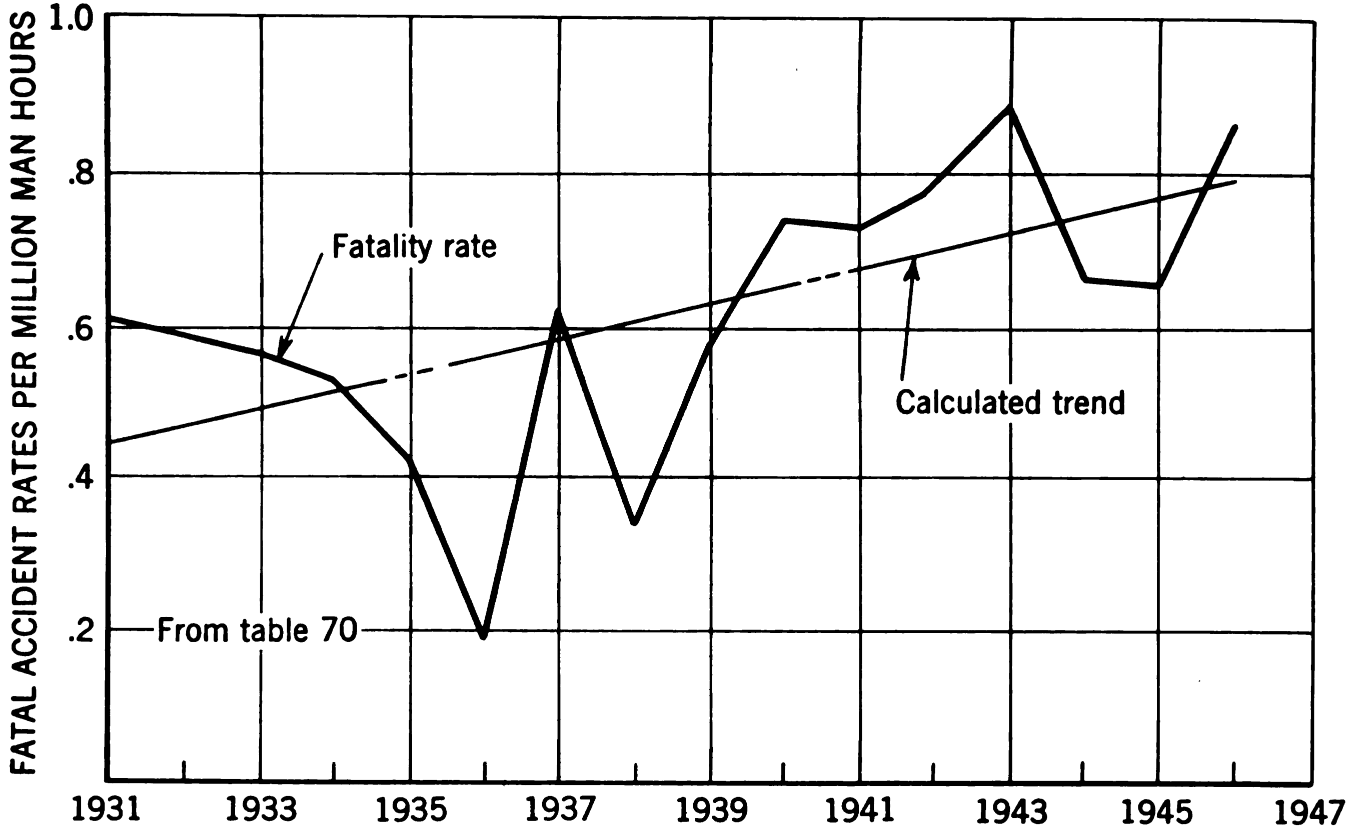

Figure 27. - Trend of fatal accidents, nonmetallic-mineral mines, based on millions of man hours.

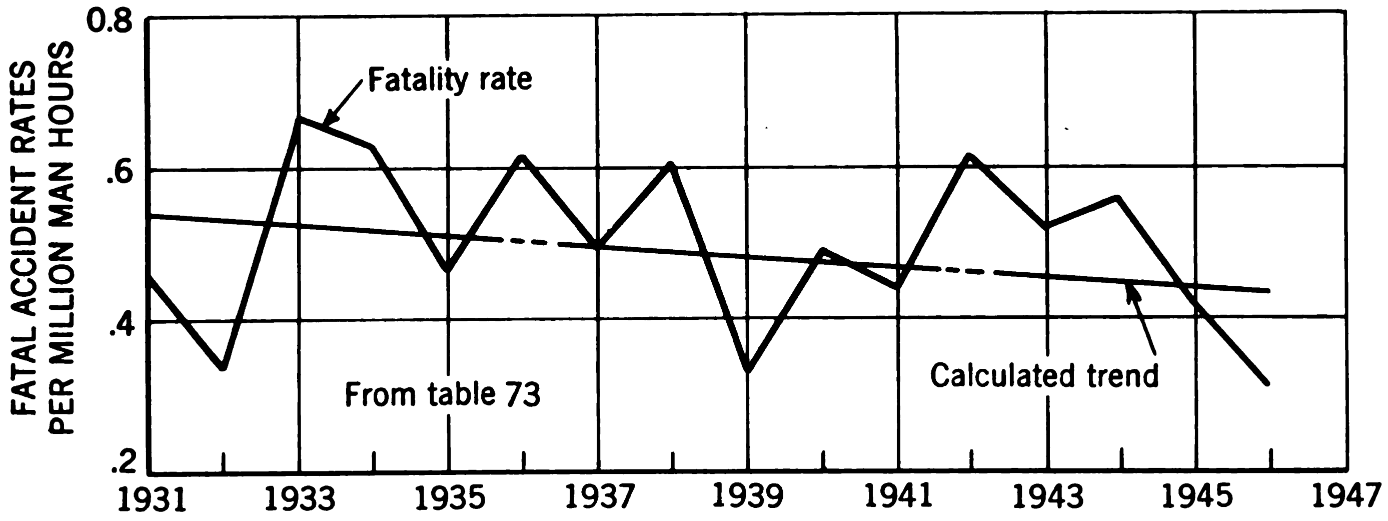

Figure 28. - Trend of fatal accidents, all quarries, based on millions of man hours.

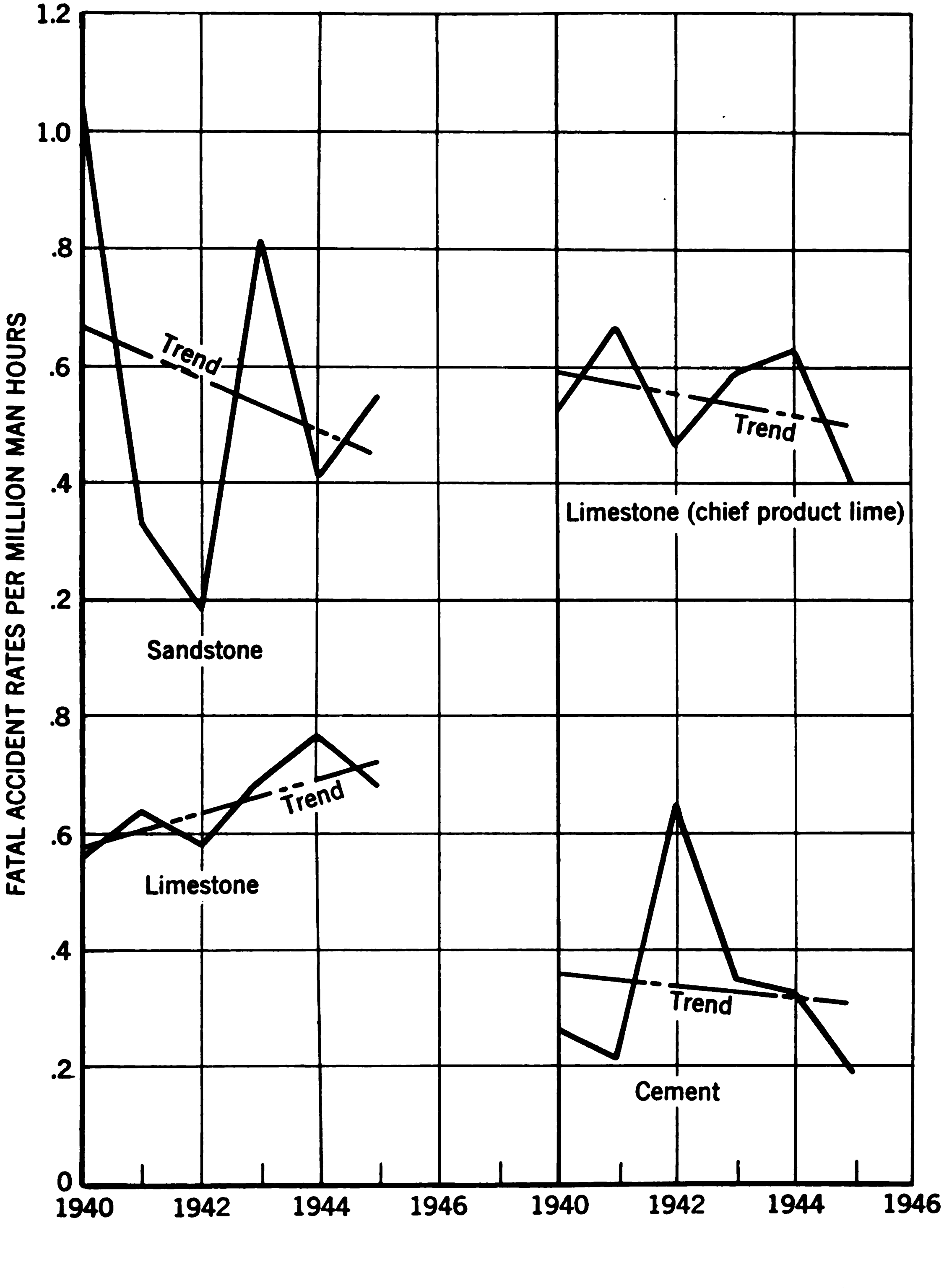

Figure 29. - Trend of fatal accidents in certain branches of the quarrying industry, based on millions of man hours.

widely done, as no decent mining company official would willingly permit conditions to exist that might be responsible for the killing or maiming of the workers. Later, through experience, it was possible to prove that accident prevention paid dividends in actual monetary savings as well, and then accident prevention became an accepted part of the operation of up-to-date progressive mines. This is particularly true of many of the larger mining companies where accurate studies have been made, records maintained over a period of years, and the dollar savings established.

Extensive studies have been made by private investigators and State and Federal agencies to determine safer practices in mining, and the results of these studies are available to all who are interested. Educational work intended to teach operating officials and workers safery ways of working and making working places more secure is carried on at many mines; State and Federal agencies provide instructors without charge, and some mining companies maintain schools where new and inexperienced men are taught safer ways of doing virtually everything required of them.

At many mines, when an inexperienced worker is employed, the practice is to set him to work with an experienced man for a few days or weeks. Unfortunately, too often this results in the inexperienced worker being taught dangerous ways of working that have been practiced for years by rule-of-thumb workers, and not the safer ways. This is particularly true of blasting, handling of explosives, and in timbering.

The ever-increasing cost of compensation to workers and their dependents for personal injuries from accidents makes accident prevention one of the major problems in mining. This problem can be solved if top management officials become really "safety conscious" and insist that accidents must be prevented; this would automatically cause supervisors to require that their employees work safely as a condition of holding their jobs. Safety in mining or in any other industry cannot be achieved unless all concerned are safety conscious and cooperate.

It is unreasonable to assume that any worker willfully performs his work so that he may be killed, maimed, or injured. Usually he does his work in a dangerous way because he does not know a safer method or because he has seen others do essentially the same thing without being hurt. Many workers refuse to believe that certain acts are dangerous because they themselves have never been injured while doing them. These and many other reasons are advanced to explain the lack of safety consciousness among many workers. The remedy lies in teaching workers safer ways of performing their work and insisting, through competent supervisors, that it be done that way. Pressure for more production may cause a supervisor to take the risk of permitting employees to take short cuts; sooner or later departure from standard safe methods of working will bring about an accident.

The employment and accident statistics of the coal-mining industry are more comprehensive than those of other branches of mining, and as a result more detailed information is available. For many years coal-mine-accident statistics were based entirely upon the rates per million tons of coal produced;

more recently man-hour statistics have been used. The statistics show that fatal-accident rates for the coal-mining industry have been reduced tremendously over a period of years, whether the rates are based upon millions of tons of coal produced or upon millions of man-hours of exposure. This is of prime importance because of the unfavorable publicity given to the accident record of the coal industry because far more publicity has been given to the occasional occurrence of a mine disaster, with the implication that these affairs are increasing, whereas the truth is that mine disasters have decreased 75 to 90 percent in number and in numbers killed by them over the past 3 or 4 decades, and a more or less similar decrease has taken place in the occurrence of all other types of accidents (fatal and nonfatal) in the same period. The fatal-accident rate per million tons of coal produced in 1906 (bituminous and anthracite) was 5.27, and in 1907 it was 6.78; these rates compare with 3.84 in 1930, 1.70 in 1945, 1.64 in 1946, and an estimated 1.72 in 1947. The rates per million man-hours were 2.057 in 1930, 1.293 in 1944, and 1.192 in 1945; later statistics based on man-hours are not available. The tremendous reduction in the fatality rate as calculated by either method is obvious.

The bituminous-coal and lignite industry has undergone far-reaching changes in the last few decades; formerly, coal was loaded almost entirely by hand, but gradually mechanized loading has been introduced in many mines, thereby increasing the output per men with some temporary increasing or changing of the hazards of mining. In 1923, only 0.3 percent of the coal mined underground was loaded mechanically; the mechanized production increased steadily, and in 1935 13.5 percent was loaded mechanically. By 1940 it had increased to 35.3 percent, and in 1945 mechanically loaded coal constituted 56.1 percent of the total coal produced at underground mines. Although mechanization of mines creates hazards, accident rates in the coal mines of the United States were much lower at the end of the period of rapid mechanization than before it began.

Coal stripping has increased in importance; the production of coal by stripping was only 4.3 percent of the total bituminous-coal and lignite mines in 1930, but in 1945 and 1946 more than 109,000,000 tons were produced from stripping operations, or approximately 19 percent of the total. The accident rate at stripping workings is much lower than in underground mining, and the increase in stripping tonnage has helped to lower the accident rate for the entire industry, even though underground mining also has shown material reduction in accident rates.

Underground bituminous-coal and lignite mines also have shown marked improvement in accident rates since 1930. The fatality rate based upon millions of tons produced in 1930 was 3.594, and this had decreased to 2.065 in 1944; the fatality rate based on million man-hours of exposure was 2.175 in 1930 and 1.379 in 1944. The nonfatal-injury rates based upon million man-hours of exposure were 95.072 in 1930 and 63.193 in 1944. These records show that much progress has been made in reducing the hazards of mining coal by underground methods and that by no means all of the reduction of accident rates in coal mining since 1930 has been due to the increased production of coal by stripping.

Major coal-mine disasters are spectacular and most of the unfavorable publicity given the coal mining industry can be attributed to them; the hazards of coal mining are emphasized and the impression is created that explosions are the principal cause of fatalities in coal mining. Statistics show that this is a fallacy, because in the 17-year period 1930-1947 major coal-mine explosions in anthracite, bituminous-coal, and lignite mines caused less than 10 percent of the fatal accidents that occurred in 12 years, and the highest percentage of fatal accidents due to explosions in the 5 remaining years of the period was 24.3 percent in 1940. 1947 was the second worst year in this period, as 23.8 percent of the total accidental deaths were caused by major explosions. The decrease in total number of coal mine disasters that occur annually is very marked when the period 1906-1947 is considered. In the 5-year period 1906-1910, a total of 84 major disasters occurred, which compares with 25 in the 5-year period 1943-1947 and 19 in 1931-1935. In the period 1906-1910, 2,492 men were killed in major disasters and in 1943-1947 547 were killed. The record low was established in 1931-1935, when 265 men lost their lives in major disasters. These records are significant when the total coal production is considered; the number of major disasters and the number of men killed in them have decreased materially, whereas coal production has increased, showing that the conditions that bring about these major disasters, particularly gas and coal-dust explosions, have been largely eliminated.

Rock dusting is one of the recognized means of averting widespread explosions in bituminous-coal and lignite mines. The number of mines using rock dust doubled between 1930 and 1943, whereas the quantity of rock dust applied to the underground workings in 1943 was four times greater than in 1930. Rock dust is not a sure preventive of widespread explosions as it is now generally applied in mines; only when most of the coal dust is removed from the floor, roof, and ribs of underground workings before rock dust is applied and the rock dust is applied to all accessible surfaces and is maintained at a minimum of 65 percent can reasonable security be assured in a nongassy mine; if the mine produces gas, the percentage of rock dust must be increased. These facts are frequently overlooked, and a sense of false security is achieved. Adequate ventilation and sufficient rock dust applied to all accessible surfaces and maintained at all times to keep the percentage of rock dust above the minimum 65 percent will do much to eliminate major explosions in bituminous-coal and lignite mines, and the cost of keeping these two essential precautionary measures in effect is less than that of most available methods of insuring a mine and its employees.

The annual production of anthracite has decreased from approximately 90,000,000 tons annually in 1910-1924 to around 55,000,000 tons in recent years. Employment decreased from a high of 179,679 in 1914 to estimated lows of 74,000 in 1945 and 77,000 in 1946. Much of the anthracite production is obtained by removing pillars, commonly referred to as second or third mining; such mining is likely to be more hazardous than mining in virgin coal. Approximately 18.0 percent of the total anthracite production was obtained from stripping in 1943, which compares with 12 percent in 1936-1939. The fatality rates based upon millions of tons of coal and millions of man-hours of exposure show a marked decrease. The fatality rate per million tons in 1910 was 7.114, and the estimated rate in 1943 was 2.867. The fatality rate per million man-hours of exposure in 1910 was 1.720, whereas the estimated rate was 1.000 in 1945 and 1.074 in 1944. The reduction in fatality rates under the conditions currently found is proof of the elimination of many hazards formerly considered inherent to anthracite mining.

Improvement in the metal and nonmetallic-mineral mining accident record over the 16-year period 1931 to 1946, inclusive, is commendable, but the record is marred by the adverse trend of the fatal-accident rate in nonmetallic-mineral mines.

The fatal accident rate in iron mines in the period 1931-1942 took an adverse trend, but since that time a marked improvement in the annual fatality rates has made the trend line virtually level. This occurred during the war years, when production was large.

Metal and nonmetallic-mineral mines as a whole can well affort to re-examine their methods and practices in connection with accident prevention, and it is probable that many improvements can be made insofar as safety for workers is concerned. Methods and practices of 25 or more years ago are still in effect in many mines, which have not taken advantage of the progress made in accident prevention.

The statistics of the quarrying industry cover both the quarries and their related plants and do not differentiate between side-hill quarries and open-pit quarries, although the conditions in them are dissimilar. The quarry industry as a whole has lowered the fatal and nonfatal accidents materially. In the 10-year period 1911-1920, an average of 164 men were killed and 9,299 injured annually; in the 10-year period 1936-1945, an average of 76 men were killed and 5,446 injured each year, a decrease of 53.5 percent in the number of fatal accidents annually.

The number of workers in quarries has been drastically reduced since 1911, when 110,954 men were employed; this compares with the employment of 58,476 workers in 1944 and 58,180 in 1945.

The cement industry has the lowest accident rate of any of the branches of the quarrying industry. The fatality rate per million man-hours in 1940 was 0.27; in 1942 it increased to 0.65 because of a major disaster due to explosives, and in 1945 it was 0.19. This industry is to be congratulated on the excellent records achieved by many of the plants in working long periods without an accident causing lost time.

The fatality rate per million man-hours of exposure in the limestone industry has increased during the 6-year period 1940-1945 from 0.56 in 1940 to 0.77 in 1944 and 0.68 in 1945. The increase in accident rates should be a cause of major concern to the industry. Limestone quarries of which the chief product is lime reduced the fatal accident rate per million man-hours from 0.53 in 1940 to 0.41 in 1945.

The progress made in accident prevention in any given commodity should be measured by comparing the numbers of workers killed or injured while attaining the required unit of production. The reduction in accidents may be attributable to changing from one mining method to another or to doing mechanically what was formerly done by hand, but if the number of accidents per unit of production is reduced, then real progress has been made.

The mining industry as a whole had done a relatively good job in preventing accidents, no matter how the accident statistics are presented or on what basis they are calculated. The number of workers killed or injured annually is less in virtually every branch and subdivision of the mining industry than it was in the past. The success of the accident prevention work should be at least as worthy of public mention as are the disasters that occur from time to time. Greater publicity in regard to the success made in mine safety might encourage mining concerns to redouble their efforts to prevent accidents and further reduce the number of workers killed or injured each year in our mines.

BIBLIOGRAPHY

Harrington, H., Fene, W. J., and Humphrey, H. C., Coal-mine explosions and coal- and metal-mine fires in the United States during the fiscal year ended June 30, 1947. 1948, 21 pp.